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NOTES AND COMMENTS.

The Failure of Metals.

Generally speaking, useful men in foundries fall into one of the three following categories—academical, technical, and practical. Of the three, probably the most useful will be found to be the technical man, as his duties are dual. In the first place, he has to find a scientific explanation of the phenomena, both common and rare, which the practical man brings before his notice, and, secondly, he has to examine the researches of the academicians to ascertain the applicability to his particular department. At the recent conjoint meeting of several scientific societies, held at the Institution of Mechanical Engineers, Westminster, a formidable quantity of failures were discussed, but few fresh suggestions were put forward which would enable the manufacturer to surmount his difficulties. It was, however, established that the greatest safeguard against time-failure was excellence of manufacture. The theory as to why metals deteriorate with time, which was more substantiated than the others, was the "amorphous cement" theory. This is based upon the properties of a thin layer of amorphous metal between the crystalline boundaries, which exists in cast or annealed material. It was strongly urged that chemical action undoubtedly increases the tendency to break in many cases, and is regarded by some as the prime cause. In 1908 Dr. Arnold submitted, in a lecture on "Factors of Safety in Marine Engineering," read before the Institute of Naval Architects, that to minimise the danger of failure under prolonged stress in steel articles it was necessary (1) to keep the phosphorus within reasonable limits, (2) to avoid "over-annealing," and (3) to discontinue the practice of hot-rolling and cold working. The first of Dr. Arnold's specifications was shown to be justified in Sir Henry Fowler's paper on "Fractures in Locomotive Boiler-Tubes," where the phosphorus was over 0.10 per cent.

Though little reference was made to the second warning, the third was brought forward in Mr. Howard's Paper, which appears in another part of this issue, where it is stated that cold-rolled rails acquire a state of internal strain. Dr. Hatfield also made reference to this cause. For season cracking in brass, the remedy put forward was suitable low-temperature annealing, which can usually be applied without injurious effect on the mechanical properties.

THE FOUNDRYMEN'S COMPETITION.

THE AWARD OF PRIZES.

We have pleasure in announcing that the first prize of thirty guineas has been won by Mr. L. Tibbenham, of 10, Temple Head, Stowmarket, and the second prize of twenty guineas by Mr. H. Lewin, of Ivy Cottage, Old Whittington, Chesterfield, and cheques have been sent to both these gentlemen. Whilst offering the prizewinners our congratulations, we would state that several others possessed many excellent features which rendered the judging an extremely difficult matter. Our readers will have the opportunity of realising the difficulty of selection, as we intend publishing from time to time some of the designs and descriptions submitted. We take this opportunity of thanking Mr. Matt. Riddell, the President of the Institution of British Foundrymen, for his kind co-operation in helping us to come to a decision. We wish also to thank all competitors for the time and trouble taken in the preparation of their matter, and trust they will accept as a consolation prize the payment which we propose to give for those selected for publication. We hope to publish in our next issue Mr. Tibbenham's design of a foundry, which without embodying anything of eccentric nature, certainly applies modern systems of transport to to an iron-foundry in an excellent and efficient manner. One very good and detailed design had to be passed, as a common entrance and exit was allowed for, between the foundry proper and the fitting shop, which was far too small in proportion to the size of foundry shown. Continuity of passage of raw, semi-finished and finished material, is an essential in any modern factory in order to minimise handling and avoid congestion. In other words, in choosing the position of any part of the plant, its relationship to the railway sidings, as well as to contributory or auxiliary plant must be seriously considerd. "Dead ends" and "return journeys" along the same route, though occasionally unavoidable, are always undesirable. Undoubtedly, the next feature to be considered is that of reasonable elasticity, without the incorporation of congestion, and here again Mr. Tibbenham has scored. We feel sure that the winning design incorporates basic principles on which a highly efficient foundry could be built.

The Failure of Metals.

On Wednesday last week, at the Institution of Mechanical Engineers, Westminster, a general discussion on the failure of metals under internal and prolonged stress was held under the conjoint auspices of the Iron and Steel Institute, the Institution of Mechanical Engineers, the Faraday Society, the Institute of Metals, the North-East Coast Institution of Engineers and Shipbuilders, the West of Scotland Iron and Steel Institute, and the Institution of Engineers and Shipbuilders in Scotland. The proceedings were divided into three sessions, at the first of which Professor A. W. Porter, D.Sc. (President of the Faraday Society) took the chair, and an introductory address was delivered by Dr. W. Rosenhain, after which the chair was taken by Capt. H. Riall Sankey, C.B. (President of the Institution of Mechanical Engineers). At the second session, in the absence of Dr. J. E. Stead, Capt. Riall Sankey continued in the chair, and at the third Eng. Vice-Admiral Sir George Goodwin (President of the Institute of Metals). Discussion was initiated by an introductory address on the subject from Dr. W. Rosenhain, followed by a series of papers, a list of which has already been given in our preliminary announcement of the meeting (see Journal, March 24 issue, page 281). We append abstracts of some of them of more immediate interest to our readers.

In his address Dr. W. Rosenhain said the main object of the discussion was the phenomenon long known by the distinctly inaccurate term "season cracking"; the title, however, had been generalised into the form "the failure of metals under internal and prolonged stress," so as to allow of the inclusion of a number of more or less analogous occurrences. It had come to be recognised that failure under internal stress, which was generally the operating cause in "season cracking," was strictly analogous to failure under the action of externally applied stress which had been operative for a very long time. It should, however, be clearly realised at the outset that prolonged stress in the sense in which the term was used in the present connection was entirely different from alternating stress or repetition stresses, such as were associated with the phenomena usually termed "fatigue." The discussion of what was ordinarily known as "fatigue," therefore, did not enter into the present subject.

It was desirable to recognise at the outset that in the tensile testing of metals the element of time entered only very slightly into the result. Numerous attempts had been made to discover whether even wide variations in the rate of loading produced any appreciable effect upon the tensile test results in ordinary metals at the ordinary temperature, and in every instance negative results had been obtained. In certain materials and in certain conditions of those materials the apparent strength depended very largely upon the time during which the load was allowed to act. It was now fully recognised that this time effect was definitely associated with a particular type of fracture. It was only in the production of intercrystalline fractures that such a time effect made itself felt, and this was a fact of fundamental importance which must be taken into full account by any theory by which it was endeavoured to explain the phenomena.

Perhaps the simplest explanation which had yet been put forward to account for the failure of metals under prolonged stress was that which, although not explicitly given, was contained in a Paper by Hatfield and Thirkell, published in 1919. This might be called the "simple stress" theory, since it implied that the actual stress existing in brass articles which subsequently undergo "spontaneous" cracking was so high as to be practically equal to the normal breaking strength of the metal, and that it only required a small amount of corrosion or of incidental damage to the surface of the article to bring about rupture. Support for this view was sought by attempts to determine the intensity of the internal stresses existing in various metal articles known to be liable to undergo cracking. It had already been shown that the method of calculating stress employed in these cases was not really satisfactory and tended to give figures much higher than the real intensities of stress existing in the material. Further, the recent work of Moore, Beckinsale and Mallinson had shown that even in brass stresses of a very much lower order than those suggested by Hatfield and Thirkell were sufficient to bring about fracture of the kind typical of the phenomena under discussion. The "simple stress" theory must therefore be ruled out entirely.

A second theory, of an entirely different kind, held a considerable amount of ground for some time past. This was based on the idea that spontaneous cracking subsequent to the completion of an article occurred only under the effect of severe cold work. According to this view, the cold-worked article contained a large amount of metal in the amorphous or hard condition. This was known to be unstable at the ordinary temperature, and it was suggested, according to the view in question, that a small amount of gradual recrystallisation took place in this amorphous material. It was known that a change of volume occurred in the transition from crystalline to amorphous or *vice versa*, and it was therefore argued that if recrystallisation occurred there was a local diminution of volume with a considerable intensification of stress, leading to the initiation of a crack. The real difficulty in connection with this theory was the insufficiency of microscopic evidence, even after prolonged and careful research, to suggest that recrystallisation could or did occur in cold-worked brass, for example, at the ordinary temperature. Until such evidence could be obtained the view that recrystallisation played any part in the cracking phenomena now under discussion must be regarded as an unsupported assumption. Further, it was difficult to see how recrystallisation of this kind would account for the intercrystalline character of the crack, which was so typical and fundamental a feature of the whole phenomenon. On the latter ground alone it would be seen that the recrystallisation theory must also be abandoned.

A third theory, which appeared to have received wide credence, particularly in America, might be called a "simple corrosion" theory. This view had been carried so far that the phenomena, widely known in England as "season cracking," were frequently referred to in America as "corrosion cracking." Recently Moore, Beckinsale and Mallinson had shown fairly definitely that general corrosion did not facilitate cracking of the kind now under discussion; neither was it possible to account for the typical intercrystalline nature of the fracture by any theory of general corrosion, although the theory of localised chemical action, quite distinct from general corrosion, put forward by Moore, Beckinsale and Mallinson, was of very considerable importance.

An explanation of an entirely different kind was derivable from the "amorphous cement" theory, according to which a thin layer of amorphous metal was present in the intercrystalline boundaries even of cast or fully annealed material. In their Paper published in 1918 Rosenhain and Archbutt put forward an explanation of the phenomena of cracking under the prolonged application of stress by intercrystalline fracture, based on the properties of the amorphous intercrystalline cement. Recently, Moore, Beckinsale and Mallinson had put forward evidence which strongly supported the view that an amorphous intercrystalline material played an important part in the phenomena, but they differed materially from Rosenhain and Archbutt in their view of the manner in which this material behaved. Both these views, which did not differ widely, were based upon a large amount of experimental evidence, and appeared to afford the only available reasonably satisfactory explanations of the phenomena.

INTERNAL SERVICE STRAINS IN STEEL.

By James E. Howard (Engineer Physicist, Interstate Commerce Commission, Washington, D.C., U.S.A.).

Practically all the materials of construction are affected by internal strains. Opposing internal strains may be present in individual members when apparently they are in a state of repose; that is, when no external forces are acting upon them.

These internal strains are no less real than those which are the direct results of external loads. The resultant strains in any given member, under working conditions, is the algebraic sum of the internal strains and those which are caused by external loads.

Under many conditions of service the state of internal strain of the material demands consideration. This is peculiarly the case with steel rails which are exposed to destructive forces and which acquire in service internal strains of high degree. Bridge members acquire internal strains, cooling strains during fabrication of component parts and strains when they are assembled, to which are finally added those due to dead and live loads.

In dealing with steel a query is at once suggested; namely, what constitutes the maximum range in strains which steel will endure, under either temporary or permanent loads and without loss of integrity. It appears to be a characteristic of the effect of alternate stresses that a reversal of direction of strain is attended with less total or aggregate elastic resilience than steel is capable of displaying when strained in one direction only. It is doubtful whether steel will be found which will endure long continued alternate stresses, in which the strains exceed a small percentage of the aggregate strains of tension and compression in separate members. In the experience of the writer the limiting stress, under repeated alternate stresses, which steels are capable of enduring, one hundred-million repetitions or more, is in the vicinity of 45,000 lbs. per sq. in. In commenting upon this feature years ago Shreve inferred from the results of Woehler and Spangenberg that 30,000 lbs. per sq. in. was the limiting stress for irons.

Judging from experience with other materials and noting also that no change occurs in the physical properties of mild steels after exposure to cubic compression several times the elastic limit in tension, it is inferred that steels will endure cubic compression without limit. Destruction of integrity of a material results from separation of the adjacent particles, but that integrity does not admit of being impaired by forces of compression when received simultaneously in three directions, however great those forces may be. It follows that the maximum intensity of a force of compression may be very great without injury provided there is a progressive graduation from the centre of effort to the periphery of the stressed area. For this reason intense impinging pressures such as those which occur between the head of a rail and the tread of a wheel, although injurious, are less damaging to the metal either of the rail or wheel than such pressures would be under conditions of uniformly distributed stresses.

In a sense, the most stable condition in which steel exists is the annealed state. It was early observed that the value of the modulus of elasticity of steel was modified when the metal was materially overstrained and had received a substantial permanent set. This value is temporarily lowered. A stress-strain curve with the steel in this condition shows an area of lost work, between ascending and descending stresses. A struggle apparently goes on within the steel to recover from this overstrained state, and after the lapse of a few days or weeks the normal value of the modulus is regained.

The denseness of steel is modified by treatment. Heating and quenching, annealing, and cold working, all result in changes in volume. It has even been found that changes in the dimensions of forgings take place more in one direction than another. By means of a strain gauge, forgings have been found to contract when annealed more in length than in lateral directions. In this behaviour of forgings there appears to be evidence of an interstructural or intermolecular state of strain which affects the general mass of the metal. This is not the usual manner of strain in which one portion of the volume in a state of internal compression is balanced by another part of the volume in a state of tension, but a diffused state of strain in which the microconstituents may play the principal parts.

Not unlikely a relation may exist between the viscous resistance of steel at forging temperatures and this interstructural state of strain. The behaviour of steel forgings in this respect suggests an interesting line of inquiry.

Internal strains make their appearance in steel cooled from the ingot or cooled after the operations of forging or rolling. The parts first to cool are usually left in a final state of compression, unless modified by complexity of form in the steel member. Earlier strains in the steel, experienced during the period of cooling, are reversed in the cold metal.

Under normal conditions of air cooling, internal strains are modified by the cross-section dimensions of the steel member. Since the acquisition of internal strains is influenced by the rate of cooling, large forgings of compact form are expected to be less affected than forgings or rolled shapes having thin webs and flanges. In steel rails, with thin flanges, internal strains of compression not infrequently reach a magnitude equivalent to a stress of 15,000 lbs. per sq. in. In the heads of the heavier rails cooling strains equivalent to 5,000 lbs. per sq. in. compression represent ordinary values.

Steel structural members, channels, angles and plates also acquire cooling strains after they emerge from the rolls. Built-up compression members, of which they may form component parts, will initially contain cooling strains of considerable magnitude. Recent examinations of structural shapes have shown the presence of internal strains of compression equivalent to 12,000 lbs. per sq. in. This value is three-fourths of the usual allowable stress for compression members in current engineering practice. Since no account is taken of the presence of internal strains in structural members exposed to compressive stresses, the omission is worthy of note.

The usual range of internal strains in air-cooled steel members may be greatly extended by accelerated rate of cooling, by exposure to a current of air, by an air blast, or by cooling with water from a medium high temperature, but not so high as to result in thermal hardening. Rapid cooling of steel rails from the finishing temperatures of the rail mill by means of an air blast is capable of introducing internal strains of compression exceeding 40,000 lbs. per sq. in. Forgings reheated to about 900 deg. F., and cooled with water acquire internal strains of compression comparable with those resulting from an air blast on rails at finishing temperatures.

Local heating followed by normal air cooling also results in the introduction of internal strains; that is to say, unequal heating of steel, as well as unequal cooling, is a cause for internal strains. By means of an oxy-acetylene torch internal strains may be introduced, and changes in dimensions effected at will, either in plus or minus directions, according to the locality on which the torch is applied. The side of the member locally heated finally contracts in length while the opposite side expands. The heated side dilates, is overstrained by the cooler and stronger side, and is eventually shortened. Admonitions upon the manner of heating and quenching machine small tools are based upon causes such as here described.

Heating by frictional resistance and quenching by the conductivity of the cold surrounding metal introduces internal strains and leads to the rupture of metals. Brake shoes in railway service furnish familiar examples of such action. The treads of wheels are occasionally affected in like manner. Examples of "wheel-burnt" rails, so called, are numbered by thousands; that is, rails which have been intensely heated along elements on the running surface of the head by the slipping of wheels. All phases of heating, quenching, and annealing are confined within shallow depths of metal on the heads of those rails, and this occasionally results in rupture. The severe structural effects which may result from wheel burning will be realised upon giving consideration to the difference in the rate of transmission of heat through the cross-section of the rail and the rate of transmission of strains.

It is necessary to exercise care in machine-tool operations to avoid the introduction of internal strains. A light feed and depth of cut, employing a tool with a sharp cutting edge, is necessary in the machining of steel in a lathe or planer to avoid the introduction of internal strains. Internal strains of compression are commonly introduced in machine operations. It has been found, however, that excessive cuts and feeds may result

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in the introduction of strains of tension. Punching and shearing of steel for use in important places has long been objected to. The introduction of high-speed, blue-chip tool steels has brought about machine-tool practice encroaching upon the objectionable features of punching and shearing.

The introduction of internal strains of most common occurrence is found in the case of steel rails in railway service. All rails are cold rolled and acquire a state of internal strain resulting from the wheel pressures. Cooling strains resulting from manufacture are present in the rails when placed in the track. These strains in part remain unaffected by subsequent conditions of service. Those in the flanges of the base commonly remain undisturbed. It is quite a different affair, however, in the head of the rail. Here the original cooling strains are immediately augmented by the wheel pressures. Internal strains in the rail head next the running surface not infrequently attain a magnitude equivalent to 20,000 lbs. per sq. in. stress. The internal strains next to the running surface are those of compression. Necessarily there must be strains of tension in some parts of the cross section of the rail to furnish the required reaction. They are found along the central zone of the head, where the measured values have reached 8,000 lbs. per sq. in. tension.

This condition acquired by the rails in the track is the explanation, in the opinion of the writer, which accounts for the development of transverse fissures. The most strained fibres in tension in the head are interior fibres. Transverse fissures commonly have their origins in eccentric position, the majority being located on the gauge side of the head. No other common cause has been found to account for the formation of these fissures of interior origin.

The idea does not appear untenable that brittleness, in the sense of inability to display permanent extension, may be displayed by steel at any temperature, under conditions of cubic tension. The only opportunity for steel to reach such a state, in which there are simultaneous strains of tension in three directions, seems to be during the operation of cooling at the period when the peripheral metal has reached a state of compression and excess tension on the interior. At some stage during the operation of cooling there is a reversal of strain from tension to compression in the peripheral metal. The higher the temperature at which this reversal takes place, the lower the prevailing tensile strength of the steel. At the finishing temperature of rails, while there is considerable viscous resistance to the steel, it then has but little tensile strength. Even with a lowered modulus of elasticity at finishing temperatures, only a minute strain would seem necessary to separate adjacent particles and prove adequate to cause these shattering cracks. Since all forged and rolled shapes are subject to cooling strains of this kind, it is obviously desirable to clear up matters connected with the phenomenon. As the case now stands, shattered zones have been found in some rails and not in others. Those which have displayed this phenomenon, by chance or otherwise, have been of the harder grades of steel.

A slight surface defect or interruption in continuity is known to have a serious effect on steels exposed to repeated alternate stresses, leading to premature rupture. This is quite evident from the failure of steels in which the structural defect was located remote from the plane of maximum fibre stress. The rupture of steel occurs when two adjacent particles are separated beyond their radius of action or molecular bond, whatever descriptive term may be used in this connection. Progressive fractures develop under such conditions. Since the presence of a surface defect produces a result similar to an increased fibre stress on the metal as a whole, it is inferred that an actual increase in fibre stress is experienced in the vicinity of the defect. Carrying the inference one step farther, it appears reasonable to believe that internal strains may augment those of external origin, the algebraic sum of the two representing the actual fibre stresses which affect the steel. Carrying the inference still farther, although now approaching a debatable state, it may be argued that actual separation of adjacent particles occurs when, and only when, the local strain between them reaches a maximum, and that this maximum has a relation to the original tensile strength of the steel. In support of this last inference is the behaviour of steel under repeated alternate stresses conducted at different temperatures. At a blue heat, in the range of 400 deg. and 600 deg. F., at which period the tensile strength is above that at ordinary temperatures, steels under repeated stresses endure several times the number of repeated loads which they sustain at atmospheric temperatures. That is, at the time of increased tensile strength there is an accompanying increase in its endurance of repeated stresses.

An unexplored field presents itself in tracing the phases through which steels pass in their approach to the final stage of rupture, involving among others the query at what stage and by means of what treatment can the progress of rupture be arrested and the steel restored to its original state. Unlimited endurance, in a practical sense, is now experienced by limiting the fibre stresses within a certain range. High initial physical properties are imparted to steels by special treatment, heat and mechanical. The question of ultimate endurance is not fully met by subjecting steels of exceptionally high original properties to a comparatively small number of alternate stresses. Results already gained are gratifying, but they still leave undetermined basic questions pertaining to long continued stresses.

Evidence does not seem to have been presented in support of the statement that any stress, however small, will cause a permanent set in steel, and that perfect elasticity or complete resilience after the application of a force of tension does not constitute a fundamental property in steels. The limited consideration which has been given to the matter of internal strains is believed to account for certain popular impressions which have gained currency.

INTERNAL STRESSES IN RELATION TO MICRO-STRUCTURE.

By J. C. W. Humfrey, O.B.E., B.A., M.Sc., M.Eng.

Uniform straining or thermal treatment of a mass of metal of ordinary homogeneity would, in so far as practical measurements are concerned, give no subsequent evidence of the presence of internal stresses; but, if we could make these measurements upon portions of a size comparable with the micro-structure, then it would appear that however uniform the original straining of the mass as a whole, yet the presence of internal stresses would always be found. In pure metals heterogeneity of structure is present owing to the varying orientation of the crystals, to their irregular shape, and, still more, to the boundary condition between them. In alloys, in addition to the above, we may find large variations in composition and strength not only between one crystal and another, but even between the parts of a single crystal. Study of the micro-structure of metals and of the mechanism of their behaviour under plastic deformation indicates that internal stresses between one crystal and another due to a previous overstrain or thermal treatment must play a large part in determining the subsequent mechanical properties.

Many of the phenomena observed in connection with the hardening of metals after plastic deformation can now be very satisfactorily explained by means of theories based upon Beiby's amorphous phase and upon the deformation of crystals by slip; there is, however, at least one important exception, for which these theories offer no explanation, but which can be accounted for if, in addition, we consider such inter-crystalline stresses as have been referred to above. The phenomenon in question is in connection with Bauschinger's theory of elastic limits, experimental verification of which was definitely obtained by Bairstow. Stated briefly it is found that if a metal is overstrained in tension and allowed to "recover" its elasticity, then in addition to the elastic limit in tension being raised the corresponding elastic limit in compression is lowered; *vice versa*, if the elastic limit in compression is raised by overstrain in compression, then at the same time the elastic limit in tension is lowered. The two elastic limits appear, in fact, always to move in the same absolute direction together, metals possessing a certain elastic range, which, while it may vary in extent, yet reaches certain limiting values.

Failures of German Steel Rolls.

CHIEF-ENGINEER K. MEERBACH, of Aix-la-Chapelle, has published in "Stahl und Eisen" the results of some investigations made by the Rolling Mill Committee of the Association of German Ironmasters in order to clear up the causes of some early failures of steel rolls. The rolls that failed had been in use in one of the rolling mills of the Rothe Erde concern, in which ingots of about 8 to 12 tons are rolled down to slabs of 80 to 125 mm. (3 to 5 in.), generally of a width of 1 metre (39⅜ in.). The usual method is to roll ingots 1,150 mm. (46 in.) wide and 750 mm. (30 in.) thick gradually down to 270 mm. (10½ in.); then place them on edge and squeeze them down to the finished width, whereafter they are again turned on their flat side and rolled out to the finished thickness. The whole operation lasts 8 to 10 min. if all goes well, but with delays due to the failing of steam pressure or other interruptions, this time is sometimes doubled.

The rolls are, as a rule, of cast or forged steel, the specified composition of which is:—Carbon, 0.25 to 0.35 per cent.; manganese, 0.50 to 0.70 per cent.; silicon, 0.10 to 0.20 per cent.; phosphorus and sulphur, if possible, not over 0.06 per cent. They are either cast in the concern's own foundry or obtained from various outside firms. In any case, slow cooling in the moulds and proper annealing are prescribed in order to neutralise any stresses in the castings. The surface of the rolls is kept smooth, except along the actual rolling surface, which is made somewhat rough in order to grip the ingots more effectually. For reasons to be explained hereafter, only the necks are cooled by water spray during rolling, but not the bodies of the rolls.

For steel rolls for breaking down ingots a tensile strength of 60 to 65 kg. per sq. mm. (38 to 41 tons per sq. in.) is specified, corresponding to a barbon content of 0.35 to 0.40 per cent. with 0.60 to 0.70 per cent. manganese. For slab rolls these percentages proved too high in the author's experience, and the carbon content was kept down to 0.20 to 0.25 per cent.

The practice of spraying the rolls with water

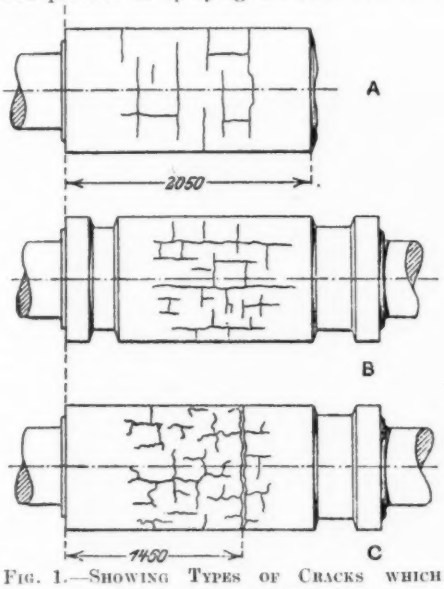

FIG. 1.—SHOWING TYPES OF CRACKS WHICH APPEARED IN DIFFERENT ROLLS.

while rolling in order to keep them cool, however, was eventually discontinued, as, instead of preventing them, it promoted the formation of surface cracks. Another factor which favoured the formation of surface cracks was that the rolling could not be timed with suitable intervals, as only two ingots were broken down per hour, which sufficed to keep the concern's finishing mills going.

The character of the surface cracks varies considerably according to (1) the process of cooling the rolls after being cast, (2) their heat-treatment, and (3) the chemical composition of the steel. Of two unannealed steel rolls one failed shortly after being put into service; the other broke after being in service for some time. Both rolls showed surface cracks as at "A" in Fig. 1. The carbon content was 0.34 and 0.31 per cent. respectively. A third roll still in use was of forged steel, and showed cracks similar to those shown at "B," Fig. 1. Finally, a fourth roll, of cast steel, which eventually broke owing to an internal heat crack, had been well annealed, and had a normal carbon content of 0.30 per cent. The surface cracks in this case had the appearance of twigs with numerous branches and sub-branches, as at "C."

One of the first-named two rolls was supplied by the outside makers as a forged roll, but a metallographic test (Fig. 2), showed that the trellis-like

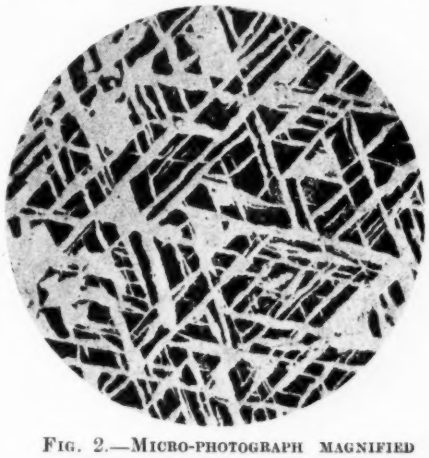

FIG. 2.—MICRO-PHOTOGRAPH MAGNIFIED 60 DRAMS, SHOWING A TYPICAL LOW-CARBON STEEL STRUCTURE "AS CAST," TAKEN FROM A ROLL SUPPLIED AS FORGED STEEL.

structure or the so-called Widmanstätten figures was evenly distributed all over the surface of the fracture, showing that the steel had neither been forged nor annealed, as specified, except at the necks.

After having dealt with surface cracks generally, the author discusses the three fractured rolls. The first roll examined was a forged steel roll of the following composition:—Carbon, 0.50; silicon, 0.35; manganese, 0.70; phosphorus, 0.06; sulphur, 0.03 per cent. The carbon content, therefore, was above normal, and the silicon sufficiently high for a steel roll used for the special purpose. The roll lasted about four months in service, and produced about 29,000 tons of slabs. It was drilled longitudinally in order to detect and remove piping. In the case under consideration this precaution did not attain the purpose aimed at, because the fracture showed piping quite close to the drilled hole. This was no doubt due to the presence of steel turnings, which had evidently been added during pouring for the purpose of cooling the molten steel, a warning example to avoid the practice of mixing easily-melting metal with the charge. The fracture was uneven, showing an outside ring (Fig. 3), with two radial fractures extending from the drilled hole at the centre to the periphery of the roll. The sector between the two radial fractures was somewhat raised above the plane of the rest of the fracture. One of the radial fractures and the rest of the broken surface was covered with rust, except the outside ring, showing that up to the moment of failure the bright outside ring and the other equally bright radial fracture formed the only connection between the two portions of the roll. It was evident from this appearance that the failure began at the centre of the cross section, and gradually spread outwards in service. The rust was due to the water used for cooling the necks having found its way into the interior of the roll along the drill hole and the crack. The outside ring, which had a few heat cracks, was remarkably thin, its width varying between 50 and 100 mm. (2 to 4 in.); within the sector it

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* Translated from a recent issue of "Stahl und Eisen."

formed a raised bead, but everywhere else it was even with the rest of the fractured surface.

Both the other two fractured rolls investigated by the author and his colleagues on the Committee were delivered at the same time, and failed shortly one after the other. The composition of one (A) was:—Carbon, 0.27; silicon, 0.47; manganese, 0.57; phosphorus, 0.080. The other (B) gave on analysis:—Carbon, 0.24; silicon, 0.35; phosphorus, 0.087; sulphur, 0.036; and manganese, 0.77 per cent. The rolls were not drilled and had not been forged; they had been annealed. They only turned out 3,800 and 8,400 tons of rolled

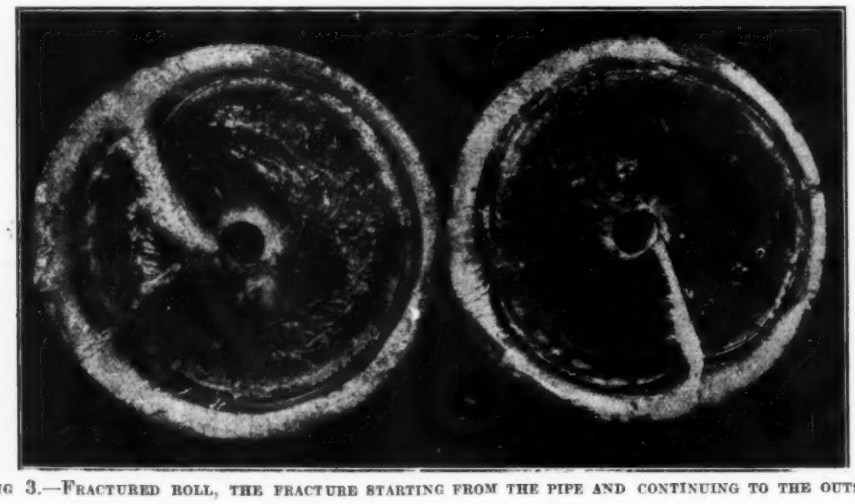

Fig 3.—Fractured roll, the fracture starting from the pipe and continuing to the outside.

material respectively. In order to cool the steel during pouring, the foundry had cast in a cylindrical skeleton frame, consisting of 15 billets, each 50 mm. (2 in) square, placed at a distance of 165 mm. (6½ in.) from the outer surface of the roll, although the use of this frame had not been specified. Both rolls showed some piping at the centre, and the rest of the fracture a well-defined dendritic structure of crystals. The working surface of the roll was covered with cracks of the twig-pattern (Fig. 1) mentioned in the introductory portion of the Paper. The fracture very clearly showed that the failure of one of these rolls was also due to an internal crack, which was originally concentric in the inner zone, but with the formation of cracks across the cross section, eccentric zones were produced which spread to the outer, the rolling surface, along about one-fifth of the periphery.

The fractured section of the other roll (Fig. 4) did not show any signs of rust, but the whole surface showed vivid colouring produced by heat, the colour changing from a dark steel-blue at the centre to a light straw colour in the region of the internal crack. The colouring was even practically all over the surface, and the difference in the colours clearly showed that the temperature at the centre of the roll differed considerably from that in the region of the circular crack. The positions of the billets embedded in the casting were indicated by light patches; moreover, the structure of the billets was of a coarser grain than that of the rest of the section. The billets were encircled by a compact coloured striped band (Fig. 4).

This striped band was also to be seen in the fractured sister roll, but the fractured surface of this roll was not coloured like in the case of the other roll, but was of a bright metallic lustre. The narrow stripes of the band were alternately yellow and of bright metallic lustre, except a few rusty places where water had reached the band along the cracks on the working surface of the roll.

The area of the cross section was divided by the band into an outer ring and the inner core. The band was not uniformly wide all round the ring; at one point it was twice as wide on one side as on the opposite side. This was no doubt due to the fact that the billets were not pitched with sufficient accuracy in a concentric circle or had shifted in a body during the pouring, and occupied an eccentric position when the metal solidified. The raised border beading was in the case of this roll even more developed than in the case of the sister roll. The metallic lustre of the fracture showed that no air found its way to the interior, as must have been the case with the other roll where the presence of air produced the vivid colouring.

Fig. 4.—Fractured cast-steel roll, showing portions discoloured, and the existence of zones. A and B are the positions from which test-samples were drilled.

Exhaustive chemical and microscopic examinations were carried out on the broken rolls, but these failed to throw any light on the exact cause of the failures.

Modern Cupola Practice.*

By W. Rawlinson.

The earlier types of furnaces, consisting of elliptical, oblong, and square shafts, are now superseded by the generally adopted cylindrical form, made wholly of steel plate or part steel plate and brickwork throughout, the stack or casing being lined with firebrick. Other forms of melting furnaces, such as air-furnaces and crucible furnaces, are ruled out on the score of cost of melting alone, except in special cases. Many types of cupolas are in use, each possessing peculiar features of design and construction, but in all types of cylindrical furnaces the fuel bed serves to carry the weight of the charges, immediately above this being placed the first metal charge followed by succeeding charges of fuel and metal.

The Object of the Process.—The basic principles of the practice are:—(1) To produce molten metal—hot and fluid—with as little alteration to the resulting mixture within limits as possible. (2) To achieve the melting in a minimum of time. (3) To expend in the melting the least possible amount of fuel. (4) The provision of a process easy to perform. In other words, the process is one of simple re-melting, with little alteration to the product as regards its constituents. The test of any furnace, therefore, is as to its ability to produce hot fluid metal in accordance with requirements, in the shortest time possible, with the least fuel consumption.

Cupola Design.—It is rather astonishing that although the process of producing cast iron, and the object in view, are simple, the design of cupolas varies so much and very little standardisation is seen. To simplify the consideration of question of design, we may conveniently divide the cupola proper into three parts:—(1) Body, where combustion of fuel and melting of metal take place. (2) Stack, where the charges are admitted and suspended, and exit for the waste gases provided. (3) Lining.

Body.—This is usually of steel plate varying in thickness according to the diameter. Broadly speaking, in cupolas of less than 6 ft. diameter, the plates are $\frac{3}{8}$ in. thick, and above 6 ft. $\frac{1}{2}$ in. thick. The body may be mounted directly on to a concrete base, forming what is known as a solid-bottom furnace, or on to a metal base-plate fitted with drop-bottom doors, through which the dump on the termination of the blow is discharged, forming what is termed a drop-bottom furnace, the base-plate being mounted on columns.

Solid-bottom furnaces have the advantage of allowing easy access in the making up of the bottom, but incur greater labour in making up the breast and in raking out at the end of the blow.

Drop-bottom furnaces have the advantage of allowing the quick dumping of the bottom at the end of the blow, and at the same time facilitating ready removal of the dump on the following day. In addition, the falling of the dump in its descent scours the lining and entails less chipping for the next blow. The latter type of furnace represents general modern practice, and the solid-bottom furnaces are passing out of use.

Tuyere Design.—Applying the test of a cupola as first set forth, namely, hot fluid melting with minimum fuel consumption, it is manifest that the crux of the whole matter is efficient combustion. Metal is melted by the burning of fuel, and proper burning of fuel is only possible when air is brought to the fuel in an efficient manner, the ideal being to supply every atom of carbon within the fuel, with its quota of oxygen.

Foundrymen are now realising that "blast" or "pressure" does not melt iron, and that excessive pressure may retard melting instead of increasing it. So long as the pressure is sufficient to drive the air in sufficient volume into the furnace, it is all that is necessary, and extra pressure means detriment to the metal, due to oxidisation, increased hardness, and chilling of the slag. It also reduces to an alarming extent the life of the lining. The design of tuyeres employed is therefore of paramount importance.

Further, the measure in which the heat valve in the fuel is abstracted and made available for melting the metal depends entirely upon the air supply, as is shown by the following equations:—

$$C + O = CO = 4{,}430 \text{ B.T.Us.}$$
$$C + O = CO_2 = 14{,}650 \text{ B.T.Us.}$$
$$CO + O = CO_2 = 4{,}200 \text{ B.T.Us.}$$

Insufficient air, or, in some cases, bad distribution of air, favours the formation of CO, and hence great loss of heat.

To burn 1 lb. of carbon to CO_2 there is required 2.66 lbs. of oxygen, or 11.5 lbs. of air. This is equivalent to 152 cub. ft. air at 70 deg. F. On the other hand, to burn 1 lb. of carbon to CO, there is required only 1.33 lbs. of oxygen, or 5.76 lbs. of air. This is equivalent to 76 cub. ft. air at 70 deg. F.

Assuming a coke with 90 per cent. carbon content, this would give a required air delivery of 10.35 lbs. of air per lb. of fuel, or 137 cub. ft. per lb. of fuel.

Assuming a ratio of 10 lbs. metal melted per lb. of coke, this means a required delivery of air into the cupola of 30,688 cub. ft. air per ton of metal melted. The generally accepted figure of air required is from 30,000 to 36,000 cub. ft. of air per ton per hour, or from 500 to 600 cub. ft. of air per ton per minute. In other words, the amount of metal that can be melted in a given cupola depends primarily upon the weight of air admitted, or, expressed another way, the volume of air admitted.

Pressure is merely force required to overcome the resistance. With the increase of resistance, as, for instance, by the blocking up of the tuyeres, the pressure, other things being equal, will also increase, but not the volume of air passing through the pipe line. A high pressure may, instead of indicating an increased volume of air, mean an actual reduction of volume. As a general figure it may be taken that the ratio of tuyere area, measured at the smallest end to the sectional area of the cupola, should be 1 to 5, or 20 per cent. For very small cupolas two tuyeres are sufficient, but for larger cupolas several tuyeres are necessary, the best design being that permitting adequate blast entrance and proper distribution.

The height of the tuyeres in relation to the bottom of the cupola depends upon conditions and the class of work to be handled. From an economy point of view, they should be as low as possible, with a maximum of 10 to 12 in. The question of holding capacity, however, governs this point; the greater the holding capacity the higher the tuyere level, but with a greater coke bed. For stove-grate work, or work where continuous tapping is possible, the tuyeres can be low down with great advantage and economy. It must be remembered that no combustion or melting takes place below the tuyeres, and hence the fuel below the tuyeres has no value for melting purposes. Further, the placing of the tuyeres high up has no advantage in keeping the metal hot. Metal can be kept quite as hot in a ladle when covered with charcoal, etc., as when remaining in the cupola. In the furnace well it has the grave disadvantage of remaining in contact with the fuel and absorbing sulphur. The only practical advantage of high tuyeres is that of storage capacity in the case of heavy castings. From the time the metal is melted to the time it reaches the well there is a drop in temperature.

Stack.—This may be wholly or partly of steel plate, of less thickness towards the top than the cupola body. Internal lining shelves should be placed at intervals to carry the brickwork and so enable small lengths of brickwork to be replaced without interfering with brickwork immediately above. A parallel stack is preferable, as any change in shape in the way of tapering only restricts the draught. The location of the charging door is more a matter of convenience than anything else. The higher it is the greater the economy of the furnace, because greater opportunity is given for the descending charge to abstract the heat from the waste gases. The limit as regards height is that of the total weight the

* A paper read before the Sheffield Branch of the Institution of British Foundrymen.

coke bed charge will bear, plus, of course, regard being paid to the design of the cupola as regards the strength of the bottom, and, further, the available air pressure. A ratio of 3 or 4 to 1 as regards the height of charging door from cupola bottom to diameter of melting zone is usual.

Lining.—Large blocks instead of bricks are now common practice and give longer life. Too great emphasis cannot be placed on the necessity of having as thin joints as possible. The weakness of the lining is the joints of the brickwork. The blocks or bricks should simply be dipped into the fireclay cement.

A parallel lining gives best results, as any taper, say, at the melting zone, only makes the charge rearrange itself, and this rearrangement allows opportunity for the gases to escape without giving up their heat. Uniform melting is facilitated by having a parallel lining.

The use of hollow cast-iron blocks instead of fire blocks is coming largely into vogue and with good results. They are undoubtedly of value, and give longer life, particularly near the charging door.

Receivers.—Much diversity of opinion exists as to the advantages or disadvantages of a receiver. The claims put forward in its favour are mainly two:—(1) It permits of the molten metal to be removed immediately from the coke bed and thus avoid contamination with sulphur and any possible chilling. (2) It furnishes a means of storage.

Against these claims has to be put the fact that metal can be kept quite as hot in a ladle, if the latter is properly covered. Further, apart from the initial cost of installation, there is the disadvantage of upkeep and the absence of any means of clearing the blockage if the connection between the cupola and the receiver becomes choked up. A receiver necessitates the cupola body being put high up, by lengthening the columns, making access to the tuyeres more difficult, or excavating in front of the receiver to accommodate the ladle. All things considered, except in special circumstances, the benefit derived from the use of a receiver is very doubtful.

Cupola Blast.—Both blowers and fans have their advantages. In the blower a definite amount of air is discharged from the blower outlet for each revolution of the impeller, irrespective of resistance, whereas the fan delivers air in the proportion in which it overcomes the resistance in front of it, and hence, with a given fan working on a particular furnace, the maximum air delivery from the fan will be obtained when the minimum resistance is offered to the air. Expressed practically, one stands to gain by installing a fan if the tuyere arrangement and general design of cupola allows of unrestricted air admission to the cupola. If the tuyeres are on the small side as regards area, a blower is undoubtedly preferable. Good melting can be performed with either fan or blower, the extent of success depending upon the design and management of the cupola.

Fans are much cheaper in first cost, and, as a rule, require less maintenance cost. The actual horse-power required to operate, for like conditions, does not differ materially, except that in the case of the blower the power absorbed is the same even when the gate valve is only partly open. In the case of the fan it is less.

The layout of the fan or blower in regard to the cupola is of great importance. It is immaterial whether the discharge is upwards, horizontal, or downwards, but it is of vital importance that the pipe line should be as straight as possible, and where change in direction is necessary, the bends should be large and of easy sweep. The nearer the fan or blower is to the cupola, within reason, the better. All pipes should be above ground and a gate valve fitted near each cupola.

Theoretically, about 84 lbs. of coke should melt one ton of iron. Allowance has to be made, however, for heat absorbed by the lining, and that used to cause the limestone to form a fusible slag, and for what is lost in the waste gases. A ratio of 10 : 1 may be considered good practice.

The pressure varies with the diameter of the cupola and the design, particularly as regards the tuyere arrangement. With ample tuyere area the minimum pressure necessary is given in Table I.

Diameter inside lining.						Ozs.	Inches
Ft.	Ins.		Ft.	Ins.		per sq. in.	water gauge.
1	6				..	8	14
2	0	—	2	3	..	9	15.6
2	6	—	3	0	..	11	19
3	6	—	4	6	..	13	22.5
5	0	—	6	0	..	15	26
6	6	—	7	0	..	16	28

Cupola Capacity.—It is difficut to state a definite relation between the diameter of the cupola inside the lining and the melting capacity. So much depends upon the design of the cupola, the air supply, and the method of operations. A general figure may be given as 10 lbs. of molten metal per hour per sq. in. cross-sectional area at the melting zone.

Given any particular size of cupola, however, and assuming it is properly managed, the two main factors are:—(1) Provision of sufficient quantity of air by volume or weight, at the requisite pressure. (2) Full opportunity for the air to get into the cupola in a manner of proper distribution. This implies correct proportioning and shape of tuyeres.

Cupola Operation.—The cupola bottom should be made of all black sand, carefully sifted, well tamped down, having a thickness of about 6 in., and having a gradual fall of $\frac{1}{2}$ to $\frac{3}{4}$ in. to the foot from the lining of the cupola to the tapping spout. The lining should be made parallel and quite straight to quite 6 in. above the top of the tuyeres. Above this point it is not necessary to fill in the lining at the melting zone perfectly straight to make up for what has burned out, but care must be taken that the lining does not become too thin.

The area of the increased diameter must be carefully watched and no short slope allowed, as this gives opportunity for bridging. The slope outwards should be gradual and up to half the height of the melting zone, and then a gradual slope in the opposite direction up to beyond the melting zone. In other words, there must be no hollows. All projections of slag, etc., should be removed when chipping out the cupola prior to getting ready for a blow. Split bricks used when the cupola is burned out are much better than ganister. These should be well hammered into a thin wall of ganister. A daubing of ganister should not be more than about 1 in. thick. Daubing mixtures may consist of equal parts of firebrick, fireclay, and silica sand, or equal parts of carborundum, fireclay, and ground crucibles. These should be mixed 24 hours before using.

Generally speaking, the coke bed should be 18 in. above the top of the tuyeres; in the case of two rows of tuyeres, this distance is measured above the top row. The bed should be well burned through before the metal is charged. All charges should be weighed, but coke can be measured in skips after a few preliminary weighings, but this measurement should be checked periodically. The coke cannot be too good, and analyses at intervals should be made. Hard, dense, sonorous coke should be chosen, with a maximum sulphur content of 0.75 per cent., a maximum ash content of 7 per cent., and a maximum moisture of 2 per cent. Coke usually contains about 12,700 B.T.U.

Instances of bad melting are often traced to wrong charges, due entirely to the guessing of quantities. With all due deference to cupola operators, it is practically impossible to estimate weights of charges. The only safe and reliable method is to weigh, and then a proper charge sheet can be drawn up, and on this continuous successful melting obtained. Uniform charging of materials is essential. The coke, pig, and scrap should spread evenly, the pig-iron being charged first, with the ends pointing to the centre of the furnace. To throw materials indiscriminately into the furnace inevitably results in getting the greater portion either all in the centre or to one side. This provides ample opportunity for the hot gases to get away without their heat being abstracted by the charge, as well as promoting conditions for producing bad combustion of fuel. The ideal is to effect even sandwiching of layers of fuel between even layers of metal. This gives conditions where the fuel is properly burned and the metal immediately above properly melted. It also guarantees uniformity in the descent and the

melting of the several charges. The charges should be kept up to the level of the charging door until the last charge is made, and towards the end of the blow the blast should be shut off to about half the supply.

The tendency of recent years has been to reduce the weight of the individual charges. If the metal charges are too heavy there is a great tendency for dull metal all through the blow. On the other hand, metal charges too light give hot metal, but with a stoppage of melting between each charge.

As a rule the metal charge placed immediately upon the bed can be 50 per cent. greater than subsequent metal charges. A safe working rule for coke charges in a properly designed and operated cupola is 10 per cent. of the metal charge, reduced as the blow proceeds, and the absorption of heat by the lining is satisfied. The longer the blow, of course, the greater the fuel economy possible.

Where possible the charges should be allowed to soak, say for one to two hours, before putting on the blast, leaving charging doors open to prevent draught. Poking of the tuyeres should be ruled out. The incoming blast will make its own passages and poking only closes them up. Poking should only be resorted to when there is a likelihood of metal getting into the tuyeres as a result of slag forming right in front of the tuyeres.

Fluxing.—Fluxes having lime as the chief constituent furnish a ready means of collecting and absorbing the silica and gangue in the pig and scrap and the ash present in the fuel. The flux used melts and combines chemically with the impurities mentioned, forming a fluid slag lighter than the molten metal. This slag serves a further object in covering the metal as it lies in the well of the furnace, and thus to some extent purifying the dropping molten metal which has to filter through the slag. Limestone is the commonly employed material and should be broken to about the size of an egg. It is best charged on the top of the metal, starting generally at the second or third charge. The quantity depends upon the cleanness of the metal charged and the nature of the fuel. As a rough figure, 50 to 60 lbs. of limestone are charged per ton of metal melted.

Fluor spar is also used. This material produces a more fluid slag than limestone, but is more objectionable to employ owing to the gases given off, and is more severe on the lining. It does, however, absorb sulphur to a greater extent than limestone. The slag formed is tapped off through the slag spout. When allowed to cool normally the slag furnishes a very good index as to the behaviour of the cupola and the success of melting. Too much limestone charged results in the destruction of the lining, the lime combining with the silica in the firebrick.

Conclusions.—As a result of his experience the lecturer has arrived at the following conclusions:—(1) The melting zone is practically that of an inverted cone, with the lowest point on a level with tuyeres, and the highest plane approximately 18 to 20 in. above the top of the top of the tuyeres. Within this area there is an absence of oxygen and a maximum of CO_2. (2) If the blast or coke bed is increased, this zone will be raised; if reduced it will be lowered. The bellying out of the cupola is the index as to where melting takes place. (3) If melting takes place lower down, the presence of oxygen will cause oxidisation. (4) The only way to obtain hot metal, with a minimum fuel consumption, and without burning of the metal, is to confine melting to just above this zone.

Cupola Troubles.

It would be a mistake to imagine that even with the best designed cupolas troubles are never experienced. When they do occur they should be carefully studied so as to prevent their recurrence and also to profit by their presence. They fall mainly under two headings, bad melting and bridging.

Bad Melting.—This may be due to many causes. The metal charges may be too heavy, and hence dull iron. The coke charges may be too heavy, and consequently the melting zone raised and irregular melting resulting. The coke charges may be too light and dull iron produced.

Charges of metal and coke may be made out of proportion and not uniform as regards the layers. Hollows just above the tuyeres will cause lodgement of the charges and irregular melting. A parallel lining is the cure for this. The blast may be insufficient in volume, or it may be badly distributed. The coke bed charge may be too low or be exhausted before charging, and, as a result, unmelted metal appears at the tuyeres. The air inlet to the blower may be clogged up or the fan not have a free, unrestricted air supply from the atmosphere. Bad pipe lines can also cause trouble.

Bridging.—This is usually due to one or both chief causes:—(1) Projections on the lining as a result of bad chipping, or hollows in the lining. A straight parallel lining will usually overcome this trouble. (2) Too severe cutting blast, either all round the furnace or at one or more points in the furnace. This quickly chills the slag and starts the bridging. A softened evenly-distributed blast is the only remedy. Irregular charging is often the cause of bridging, as also is bad "daubing," when certain parts of the daubing come adrift and fall into the furnace near the lining. Bad coke can be another cause.

Charging Devices and Handling of Materials.—There are few foundries now that convey materials to the cupolas by hand, mechanical lifts, operated by belt, pneumatically or electrically, being in general use. In point of cost the belt-operated lift is cheaper than either pneumatic or electric, the pneumatic being cheaper than the electric. The efficiency of lifts is increased by using small bogies which run on rails on the charging platform, right up to the charging door. Latterly, handling by means of Telpher or small travelling crane has proved an economical and expeditious proposition. With this system the charging platform is done away with, all materials being handled on the ground level.

Small bogies are used, and are loaded at the various stock bins, and then passed to the weighing machine. They are picked up by the crane and taken right to the charging door. By means of a drop front or bottom in the bogie, and a suitable chute in the charging mouth, the contents can be dumped straight into the cupola. This arrangement saves considerable labour, as well as the cost of the charging platform.

Instead of a Telpher or travelling crane, I beams may be used with pneumatic hoists mounted on trolleys.

Cupola charging machines are also in use, particularly on the Continent. These are self-contained, and operated by a single motor. Usually they serve two or three cupolas. Bogies or grab buckets serve to carry the materials, and these are loaded directly from the stock yard and weighed. They are conveyed up the transporter, and the contents charged directly into the cupola. Here again no charging platform is required, and the saving in labour is very considerable.

Magnets.—These are coming into very general use for handling pig-iron and scrap iron. Their chief advantage lies in the fact that slinging and loading operations are done away with, and metal can readily be unloaded from the trucks and later conveyed to the charging platform. Only direct current can be used during operation.

Generally speaking, small magnets can lift about 20 times their own weight, magnets about 3 ft. in diameter about 10 times their own weight, and magnets of 5 ft. diameter about 6 to 7 times their own weight. In the case of pig-iron or scrap iron only some 10-12 per cent. of the maximum solid weight that a magnet can lift can be attracted, depending, of course, upon the conditions under which the metal is stacked and the nature of the material.

Many attempts have been made to radically alter the design of cupolas with a view to giving a greater efficiency, particularly as regards fuel consumption. It cannot be contended that even the best of cupolas is an unqualified success, because under the most favourable conditions the thermal efficiency is only in the neighbourhood of 30 per cent. Several factors enter into this side of the question, apart from cupola design, particularly when it is remembered that something like 10 per cent. of the fuel value is absorbed by the lining and 30 to 50 per cent. of the fuel value goes up the stack unused.

Influence of Manganese on Strength of Malleable Castings.*

Some authorities, like Ledebur, consider that the percentage of manganese in malleable castings should not exceed 0.4 per cent., while others entirely disagree with him. To settle this moot point, Dr. E. Leuenberger, of Schaffhausen, has

TABLE I.—*Analysis of Unannealed Material.*

Charge	Mn	C	Si	P	S
	%	%	%	%	%
1	0.13	3.06	0.45	0.071	0.041
2	0.26	2.6	0.41	0.078	0.042
3	0.38	3.18	0.32	0.089	0.042
4	0.66	2.58	0.44	0.075	0.044
5	0.78	3.11	0.44	0.078	0.054
6	0.80	2.76	0.47	0.068	0.044
7	0.94	2.76	0.39	0.068	0.050
8	1.05	2.58	0.51	0.056	0.054
9	1.12	2.9	0.41	0.087	0.038
10	1.32	2.82	0.33	0.072	0.038
11	1.52	2.99	0.45	0.076	0.044
12	1.74	3.30	0.36	0.097	0.040
Average	—	2.89	0.41	0.076	0.041

carried out special tests on malleable cast iron of which the manganese content varied from 0.13 to 1.74 per cent. in 12 charges. The chemical composition of the 12 is shown in Table I. The test-pieces were divided into three sets, the first of which (Series I.) was annealed at a temperature of 980 deg. C. for 95 hours, the second (Series II.) for 130 hours, and the third set (Series III.) for 260 hours. Each set consisted of six dozen each, percentage of manganese content being represented by six pieces. After being annealed the test pieces were subjected to tensile test, and the elongation on 4 in. as well as the ultimate strength were carefully recorded for each. The averages are shown in Table II., and also in the three diagrams annexed herewith. The test pieces were round bars of 12 mm. tested in their cast state, unmachined.

tion, as it has a tendency to produce piping and cracks and makes the production of thin castings difficult.

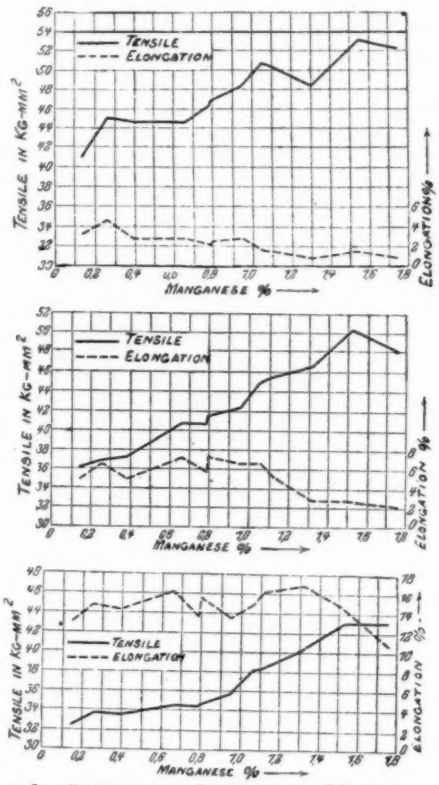

FIG. 1.—SHOWING THE INFLUENCE OF MANGANESE ON THE TENSILE PROPERTIES OF MALLEABLE CAST-IRON.

TABLE II.—*Tensile Strength and Elongation on 4 in. (Averages).*

Manganese per cent.	0.13	0.26	0.38	0.66	0.78	0.80	0.94	1.05	1.12	1.32	1.52	1.74
SERIES I.												
Kg. p. sq. mm.	41.2	45.0	44.6	44.7	46.4	47.0	48.4	50.8	50.4	48.5	53.1	52.2
Tons p. sq. in.	26.1	28.58	28.32	28.38	29.46	29.85	30.73	32.26	32.00	30.80	33.72	33.15
Elongation per cent.	3.5	4.5	3.0	3.0	2.5	2.7	3.0	2.25	[2.0	1.5	2.0	1.5
SERIES II.												
Kg. p. sq. mm.	36.1	36.9	37.2	40.8	40.5	41.6	42.3	45.0	45.6	46.6	50.3	48.0
Tons p. sq. in.	22.92	23.43	23 62	25.91	25.72	26.42	26.86	28.58	28.96	29.59	31.94	30.48
Elongation per cent.	5.0	6.0	4.8	6.5	5.5	6.5	6.0	6.0	5.0	3.0	3.0	2.0
SERIES III.												
Kg. p. sq. mm.	32.5	33.5	33.3	34.6	34.5	34.6	35.6	38.0	38.4	40.7	43.2	43.2
Tons p. sq. in.	20.64	21.27	21.15	21.97	21.91	21.97	22.61	24.13	24.38	25.84	27.43	27.4
Elongation	13.0	14.5	14.0	15.5	13.5	15.0	13.5	14.5	15.5	16.0	14.25	11.03

SERIES I. annealed for 95 hours; SERIES II for 130 hours; SERIES III for 260 hours.

The author has published the results of his tests in great detail in a recent issue of "Stahl und Eisen," and summarises them as under:—

(1) The tensile strength of the iron diminishes with increasing manganese content.

(2) Up to about 1 per cent. the manganese does not influence the elongation. A higher percentage, however, reduces elongation.

(3) The tensile strength is reduced by prolonged annealing, but elongation is increased in proportion.

(4) The longer the period of annealing lasts, the higher may be the manganese content without affecting unfavourably the elongation.

A reference to the three diagrams will show how far these conclusions are correct.

The author utters a warning that although manganese may improve the physical properties of malleable castings it is to be used with great cau-

* Translated from "Stahl und Eisen."

FRENCH CAST-IRON PIPES FOR THE DUTCH INDIES.—The news that Messrs. Pont à Mousson, whose factories were almost destroyed during the war, have received an important order for the supplying of cast-iron pipes from the town of Batavia (Dutch Indies), has been received with satisfaction in French foundry circles.

MARKET FOR FOUNDRY COKE IN HUNGARY.—The British Commercial Commissioner for Hungary (Mr. R. J. E. Humphreys) reports to the Department of Overseas Trade that there is a demand for British foundry coke in Hungary in spite of its high price, on account of its superiority to that obtained from other sources. United Kingdom exporters should apply to the Department of Overseas Trade, 35, Old Queen Street, Westminster, S.W.1, for a list of importers and users of coke in Hungary, and should quote the reference number 7698/FW/PN.

The Pattern Store.—II.

The lay-out of the store for the housing of patterns used in connection with a repetition line of manufacture is a fairly simple proposition, for the amount of storage space can be predetermined, as the sizes of the patterns and the number of each to be stored is already known.

The method of storing can follow on the lines laid down for manufacture, that is to say, if the completed unit is manufactured by way of a series of assemblies, then it may be possible to store all the patterns for use in connection with one assembly in close proximity, to allow of easy access. Objection may be made to this method on the grounds that one assembly would require both large and small patterns, but this could be met by making the division of the storage bins vertical instead of horizontal, this ensuring for each assembly a number of the ground bins for the storage of the large patterns, the smaller patterns for each assembly being housed higher up.

The whole of the ground bins along the bay would be of ample dimensions, so as to accommodate the largest of patterns, and also plate patterns. It may be observed here that the method suggested is intended for a medium size class of manufacture, as where very large castings are required, special arrangements for the storage of the patterns must be made.

For repetition purposes the working patterns are usually of metal, either cast-iron or a brass alloy. There must of course be a wood master pattern, whilst in some instances there is a metal master pattern. The record therefore must be comprehensive, and the storage must be arranged so that confusion will not arise.

It is not desirable for wood and metal patterns to be stored together, so it would seem that the best method is for part of the store to be given over entirely to the wood master patterns. These patterns are not liable to be called for frequently and can therefore be kept at the rear of the store so long as the record clearly indicates their location.

When the new wood master is made, it is a matter for arrangement whether this shall come to the store, or be sent direct to the foundry with an order for working patterns. If the foundry is attached to the factory, the latter procedure is often followed, but if castings are to be obtained from outside foundries, then the wood master must be received in the store, and issued out upon the demand of the purchasing department.

The metal working-patterns having been made, these are received into store, and a record card made out. This, as will be seen from the illustration, gives particulars relating to the wood master and also to the metal patterns. Space is allowed for subsequent issues and returns, and it may be observed that these cover issues to the pattern shop for renovations, as well as to the foundry.

It is probable that there is more than one working pattern made from each master, and this fact must be duly recorded. Each pattern bears the number of the master, and in addition its own identification number. So assuming that five working patterns have been made off the wood master number 1415, the first metal pattern would be numbered 1415-1, the second 1415-2, and so on A special record is kept of each, for it may be that on one occasion patterns 1, 2 and 3 will be sent together to one foundry, whilst upon another occasion patterns 2 and 4 will go to the same foundry.

When a demand comes to the store for patterns, the number required must be stated. In certain cases the number of patterns required to fill a box is made, and when a demand is made the full number must be issued. In other cases, however, the necessity for a definite number is not so apparent, as a few patterns are always kept in reserve. So the purchasing department, or the foundry, should always state whether one, two or half a dozen patterns are required.

When core-boxes are used, these should be definitely identified with the pattern, the same number being used. There is a tendency in many factories to keep the number of core-boxes as low as possible, and although it is perhaps unnecessary for a core-box to be made for each individual working pattern, the quantity made should be sufficient to allow for a fairly wide distribution of patterns. In the case of the home foundry the question does not as a rule arise, but when castings must be obtained from outside the action of the purchasing department is often checked by an inadequate supply of core-boxes.

It may be that there are six patterns and only two core-boxes, and this means that orders can be placed with but two foundries at one time. Whilst in the main this may be sufficient, there are times when it would be an advantage to send two patterns to each of three foundries, and this aspect of the question should not be ignored.

The storekeeper must know when core-boxes are required, and supply these when the patterns are called for. He must also see that they are returned, as often they are omitted when the patterns are sent back at the finish of an order. A pattern received without the core-box should not be put into store, but a notification should be sent to the foundry or to the purchasing department, whichever is responsible.

The question of plate patterns may lead to complications, unless intelligent records are compiled, this applying particularly to those parts for which both plate and loose patterns are in evidence. Dealing first with the part for which a plate pattern only is provided, the record in the first instance deals with the wood master. This in due course is sent to the foundry for a supply of cast working patterns, and the record then is governed by the method favoured for the building up of the plate pattern.

PATTERN RECORD.

Location.....

Name of Component ..... Component No. ..... Pattern Number .....

Wood Pattern Made..... Metal Patterns Made..... Plate Pattern Made .....

Number of Working Patterns..... Made by .....

Wood Pattern.		Working Pattern No.		Working Pattern No.		Working Pattern No.	
Date.	Whereabouts.	Date.	Whereabouts.	Date.	Whereabouts.	Date.	Whereabouts.

Assuming that the piece for which the pattern is required is of fairly small dimensions, and that twelve patterns can be accommodated upon one plate. It may be that these twelve patterns are received into the store, and then sent to the foundry for castings to be made direct on to the plate. This means that, in course of time, these twelve patterns will be received back into the store, but on account of the extra contraction allowance they cannot be used for obtaining castings for production purposes, these castings being obtained from the plate pattern. To guard against the possibility of these patterns being sent to the foundry for use in connection with a production order, it may be considered desirable to scrap them, but if this course is not favoured the record must state clearly what they are, and so prevent confusion.

If the method of screwing the patterns on to the plate is favoured, the extra set of patterns is not in evidence, as those cast off the wood master are the actual working patterns, these being worked up and affixed to the plate. This is not intended to be a treatise upon pattern shop and foundry methods, but it is essential that the methods are understood by the pattern storekeeper, otherwise trouble will certainly follow.

When, in course of time, the development of the part warrants the making of a plate pattern, it is sometimes considered desirable to retain the loose patterns, using these as parts or auxiliaries. In this case there should be two record cards, one for the loose patterns, and one for the plate, each card bearing a cross reference to the other. The record card for the plate pattern will give particulars of the new wood master, and any other patterns used in connection.

The storekeeper must see that the loose patterns are not confused, for it may be that there are say six patterns which can be used for production purposes, and six others which, on account of the contraction allowance, cannot so be used. The difference is of course so slight as to be undiscernible until the castings are put in hand for machining, when the mischief is irreparable.

The records are most important, and amply repay the time expended upon them, for a satisfactory answer, without loss of time, is accorded any inquiry. The whereabouts of each pattern should be precise. If all castings are made in the factory, the word "foundry," with the date and the order or batch number, will denote that the pattern is in commission, whilst the words "inspection" "pattern shop" or "store" are self-explanatory.

When castings are purchased outside, the word "foundry" is not really sufficient. In this case the name of the specific foundry to which the pattern has been sent should be stated, and as this information is given by the purchasing department when the demand for the pattern is made, no extra work is occasioned.

If the storekeeper is responsible for the packing and despatch of the pattern, he must appreciate that certain patterns may easily sustain damage, and pack with a view to eliminating the contingency.

CHROMIUM ORE.—A new volume dealing with chromium ore, in the series of monographs on the Mineral Resources of the Empire, has just been published by Mr. John Murray (price 3s. 6d.). It is written by Mr. W. G. Rumbold, of the Scientific and Technical Department of the Imperial Institute, under the direction of the Mineral Resources Committee of the Institute. The first chapter of the monograph deals with chromite and other chromium minerals; the valuation prices, and world's production of chromite; the concentration of the ore and its utilisation. In the second chapter, the chromite deposits of the British Empire are described in detail, especially those of Selukwe, in Southern Rhodesia, and of Quebec. In the third and last chapter the chromite deposits of foreign countries are described, particularly those of Greece, Asia Minor, New Caledonia, Cuba and the United States. Statistical tables of imports and exports, production, etc., are given, whenever the necessary data were available. The work concluded with a map showing the principal chromite deposits of the world and a list of publications on the subject.

Alloy Steels for Large Forgings.

Before the Staffordshire Iron and Steel Institute last Saturday Dr. Leslie Aitchison, D.Met., B.Sc., read a Paper on "Alloy Steels for Large Forgings," from which we give the following extracts:—

It is reasonably safe to assume that alloy steels are only used in those forgings which must necessarily be made of steel having a high order of mechanical properties. It is well known that with carbon steel there is a limit to the strength which can be obtained if a reasonable degree of ductility is to be retained. Even in small sized bars it is not easy to obtain more than, say, 45 tons per sq. in. from plain carbon steels, and at the same time to have a good degree of ductility and toughness.

The variation in the strength of the different parts of the large bar of heat-treated carbon steel is due to the well known effect of mass in hardening. This mass effect arises from the obvious fact that during quenching, in oil or water, the outside of the quenched part cools much more rapidly than the inside, and that whereas the rate of cooling of the exterior may be equal to or greater than the critical rate of cooling required to harden the steel, that of the interior is below this critical rate and that consequently the steel in this part is not hardened or is only partially hardened.

Clearly the degree to which mass effect is found in a steel depends upon the critical rate of hardening of that steel. If one steel will harden when cooled relatively slowly and another steel will not harden, it is evident that the former steel will suffer less than the latter from mass effect. One of the pre-eminent virtues of the alloy steels is, that they possess a relatively low critical rate of hardening, and therefore that in large masses, in which the rate of cooling the interior may be quite low, it is still sufficiently high to equal or to exceed the critical rate of hardening the steel.

Consequently it is possible with alloy steels to obtain much more nearly homogeneous results in large parts and to induce a more uniform degree of hardness throughout the article.

The comparative immunity from mass effect is not found to the same extent in all alloy steels; it is most evident in alloy steels which harden completely when cooled in the air and is least evident in those steels which do not harden at all when cooled in this way.

Generally speaking, the steels which possess the property of air hardening in the greatest degree, are all nickel chromium steels. Of this class of steel those which are most pronouncedly air hardening are those which contain more than 3.0 per cent. of nickel, and 1.0 per cent. or more of chromium. The truly air-hardening steels have approximately 4.0 per cent. of nickel and 1.1 or 1.2 per cent. of chromium. If the percentage of nickel falls below 3.75, or if the proportion of chromium falls below 0.9 per cent., the steel possesses a distinctly smaller capacity for air hardening, and hence should be avoided for the manufacture of the largest forgings.

The alloy steels which are not nickel chromium steels, and which are likely to be used for forgings, are either straight nickel steels or straight chromium steels. Neither of these classes of steel show any marked air hardening properties, the low chromium steels showing less than the nickel. Although such steels do not harden in the air they harden very well in oil and are very suitable for moderate sized forgings which can be quenched in oil.

Of the alloy steels which are suitable for the manufacture of large forgings, the following seem to be the most appropriate:—(*a*) 3 per cent. nickel steel; (*b*) nickel chromium steel with more than 4 per cent. of nickel and 1.1 per cent. of chromium; (*c*) nickel chromium steel with from 3 to 4 per cent. of nickel and from 0.75 to 0.9 per cent. of chromium.

The 3 per cent. nickel steel is really only fitted for those alloy steel forgings in which a moderately low strength is called for. Fortunately such parts are fairly numerous, and the steel normally serves them well. If the forgings are very large, 3 per cent. nickel steel is not to be recommended even for the lower strengths, for, although it hardens in oil very effectively, it has no air hardening properties of any value, and in big forgings the mass effect in hardening becomes noticeable. The other nickel chromium steel is particularly useful "omnibus" steel. By slight modifications of chemical analysis it can be made (after heat treatment) to give a fairly wide range of strengths, and when tempered well down its toughness is excellent. The steel has moderate air hardening properties—not so good as steel (*b*) but distinctly better than steel (*a*). As a result, it fits well for fairly large forgings.

In making large forgings it is, of course, necessary to commence with large ingots. In general it may be said at once that all those defects which are found in large ingots of plain carbon steel are also present in large ingots of alloy steel. The surface of every steel

ingot is more or less rough, and a rough surface means of necessity the existence of sharp corners, small notches or grooves of small radius. If the roughness of the surface of the ingot results in the presence of any sharp corners or notches, these defects will multiply considerably any stress to which the steel in the ingot is subjected. The contraction of the ingot which must occur during the time that the ingot is cooling after solidification introduces considerable stresses in the steel. These will be intensified by the irregularities of the surface of the ingot, and it may easily happen that the stresses are concentrated to such a value that they exceed the yield point of the metal. If this value of stress is reached, the metal at the part of the greatest concentration of stress must either distort or break.

Carbon steels are much more ductile than alloy steels, and it is also known that the ductility of the remainder varies more or less inversely as the maximum stress of the part after air cooling. Alloy steels, and particularly those which harden to an appreciably high maximum stress when cooled in the air, are much more likely to crack on the surface whilst cooling in the air than are the carbon steels.

The influence of the surface defects of the steel upon the tendency to form dangerous cracks in the interior of the steel is not confined to the steel in the ingot form. Even though the actual stresses set up may be less on the average, the probability of an increase in the stresses to a dangerous concentration will be greater in the billet than in the ingot. This is due to the fact that the original surface flaws in the ingot have been intensified by the forging operation, because the corners will have been covered over and squeezed together, and therefore rendered sharper at the root. On the whole, therefore, it may be said that forged material is even more prone than the cast material to develop surface (and therefore growing) flaws.

It has been the practice amongst steel makers to deal with surface defects by chipping. In both these methods, and particularly chipping, the metal round the crack is very apt to be burred over and to prevent the careful examination of the metal which is necessary in order to determine whether or not the crack has been entirely removed. A far better method of removing these flaws is by rough turning or planing the bloom or billet. In large forgings, the speed of cooling is small unless the parts are quenched in oil or water from the tempering temperature. This practice should always be adopted.

Mould-Carrying and Pouring Devices

By J. E. McDonald.

The arduous work of handling the finished moulds by hand has been secured by a number of ingenious installations in the squeezer department of the Modern Foundry Company in the Oakley colony of Cincinnati. Fig. 1 shows a mould-carrying device built on the conveyor principle, consists of an inclined track along which the finished moulds are carried. The squeezer machine is located directly at one end of the track, and the moulder stands immediately behind it, facing the

FIG. 1.—SHOWING MOULD-CARRYING DEVICE.

front of the floor. Sand and boards are placed conveniently alongside of the machine. The mould is made in the ordinary manner, and, when completed, the moulder pulls a lever which actuates a three-way valve to an air cylinder placed between the rails of the track immediately in front of the machine. The release of the valve operates a cross slide connected with counterweighted tilting dogs fixed at the upper end. Upon the operation of the cylinder the dogs slide under and beyond the bottom board of the completed mould, and the counterweights cause it to assume an upright position. The lever controlling the valve is then reversed, and the dogs engage the bottom board of the mould, which is gently pulled down the inclined tracks. As the mould leaves the machine a centreing device engages the battens of the bottom board, thereby ensuring the alignment of the moulds. This operation is repeated with each mould, the last one coming from the machine gently pushing the preceding ones along the track until they are picked up with the lifting device and placed on the floor to be poured. The average weight of each mould is 160 lbs., and the track, constructed of 12lb. rails, holds 30 moulds. The track is 36 ft. long, and the rails are placed 10 in. between centres. The incline is 2 in 30, and a section 6 ft. is laid flat on the floor. This device can be applied to practically any moulding machine now on the market.

The special pouring device shown in Fig. 2 consists of a steel frame, boxed in with Transite board, and a crank handle which hooks to the trunnions for tipping the ladle. The device is attached by a chain hoist to an overhead crane, and can be very easily moved to any point desired. With this device, the heavy work of carrying the ladles by hand, with the accompanying spilling of iron, is entirely eliminated, and one man is able to handle three times as much metal as could be done with a hand ladle. In its construction special attention was paid to the protection of the operator, and its use has very materially reduced the number of severe burns usually associated with hand-pouring. Better pouring, with very little fatigue to the operator, has also resulted.

The ladles used in pouring off have a capacity of 400 lbs. each, and are provided with special bails

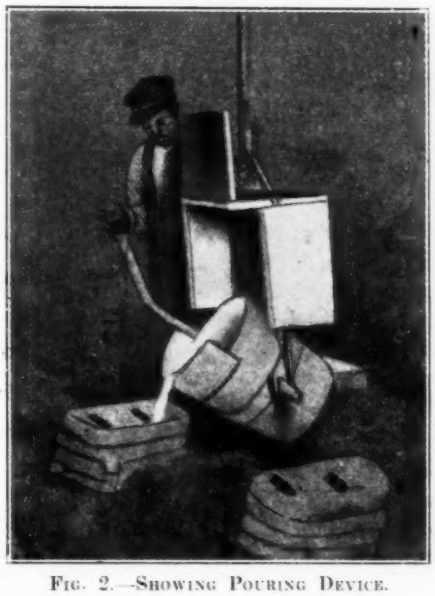

FIG. 2.—SHOWING POURING DEVICE.

and trunnions fastened permanently to them. The ladles are filled at the cupola and are transported, three at a time, by an electric lift truck, to the department where the moulds are to be poured. By pouring direct from the ladles the loss of heat resulting from transferring the iron to a hand ladle is done away with. The ladles are provided with skimmers to prevent slag and oxides from entering the moulds. At present seven mould-carrying tracks are in operation.—"Iron Age."

His Majesty's Consul at Helsingfors (Mr. C. H. Mackie) has forwarded two copies of each of the specification and blue prints giving particulars of 4,800 tons of rails, 250 tons of fish plates, and 500 tons of the plates, required for the Finland State Railways, tenders for the supply of which material are invited by the Finnish Board of Ways and Communications. Sealed tenders, marked "Tender for Rails and Accessories," to the "Ofverstyrelsen for Vag-och Vattenbyggna derna i Finland," not later than April 30. One of the above-mentioned sets may be seen by United Kingdom firms interested at the Enquiry Room of the Department of Overseas Trade, 35, Old Queen Street, Westminster, S.W.1.

XUM

Institution of British Foundrymen.

COVENTRY BRANCH.

A meeting of the Coventry Branch of the Institution of British Foundrymen was held at the Oddfellows' Hall, Coventry, on Tuesday, March 15, 1921, when a lecture was given by Professor T. Turner, M.Sc., A.R.S.M., F.I.C., entitled "Carbon in Iron and Steel." Mr. F. H. Hurren (Branch-President) presided over a large attendance.

Carbon in Iron and Steel.

Professor Turner said that when he was asked to come to Coventry he had explained that he could not offer to present to them any of the more recent investigations such as might perhaps be of interest to the senior institutions, and that he had proposed to tell them things which were more or less common knowledge to those acquainted with the scientific aspects of the foundries. He understood that their Branch consisted of three types of members. One was composed of those who were connected with the laboratories of the leading firms in the city, and might therefore be assumed to be at home with the subject and to be able to read papers themselves. Then there were those who were quite young and had comparatively little metallurgical knowledge, and who required to attend some systematic course of instruction covering the ground work necessary in order to understand things. But he believed that there were a considerable number who, whilst they had a good deal of practical experience, had also some scientific knowledge but wanted more. It was to that class he proposed to address his remarks.

He assumed that they already had some acquaintance with the chemical principles, and therefore proposed to convert his Paper into an informal talk. In the first place, iron in a pure condition was a relatively soft, ductile metal with a tensile strength of some 20 tons to the square inch and a high melting point. From a foundrymen's standpoint pure iron was of comparatively little interest. With the addition of a relatively small quantity of carbon, at a higher temperature, it became so fusible that it could be melted in a crucible and took such a good impression of the mould that they got castings of good appearance. The essential element in cast-iron and steel was carbon. Starting with iron, the proportion of carbon varied from nothing to 4½ per cent., and according to the amount of carbon and to the form in which it appeared they had a wonderful variety of material. They had material which was soft and ductile, or which was easily fusible, and which possessed many other varied properties, and it was due largely to this fact that they could get such a wide variation in the properties that iron was the one great valuable metal to mankind. There were always, of course, other elements present, such as silicon, but that was important chiefly on account of its influence upon the carbon. Sulphur was also chiefly important for the same reason. Phosphorus made the metal more fluid, enabling them to obtain cleaner castings. If present in large quantities it caused brittleness. Manganese had an effect both upon the iron itself and also on the carbon.

When dealing with the entry of carbon into the iron they had to consider the proportions in which it was present, the various conditions in which it exists, and the properties which carbon conferred upon the iron. They must remember that pure iron melted at the high temperature of about 1,527 deg. C.

With the aid of a diagram which he built up on the blackboard as he proceeded with the lecture, Professor Turner explained the constitution of the iron-carbon series and how the iron contracted and expanded at different temperatures. Above 900 deg. C. it was called Gamma iron, and was supposed to be hard. One of its properties was that it would dissolve carbon. Below that point the iron either did not dissolve carbon at all or dissolved it very slowly. They could never get a perfectly pure iron in practice, as there was always a certain quantity of carbon present.

By means of a series of slides, the lecturer illustrated the structure of different irons containing various proportions of carbon, commencing with nothing and going up to 4½ per cent. As the carbon was added, the temperature at which the metal melted was lowered, and the metal became more fusible. With a percentage of 4⅓ of carbon the iron melted at 1,130 deg. C. If more carbon was added the melting-point rose again. With 6⅔ per cent. of carbon, they reached the extreme carbon content on the ordinary methods of working with a Siemens furnace or an electric furnace. At over 3,000 degrees they had compounds corresponding to Fe_2C. to FeC. These compounds decomposed on cooling, liberating carbon and leaving iron carbide (Fe_3C), which on further cooling yielded carbon and the 4.3 per cent. iron-iron-carbide eutectic,—the wood eutectic, meaning "well melting"; they had the syllable "eu" as in such words as euphonious.

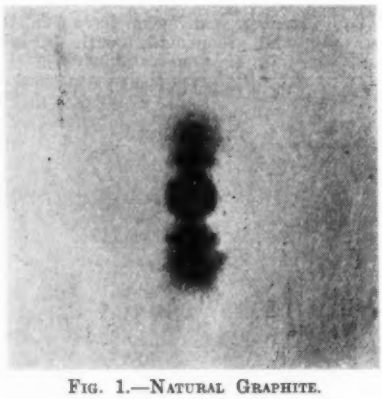

Fig. 1.—Natural Graphite.

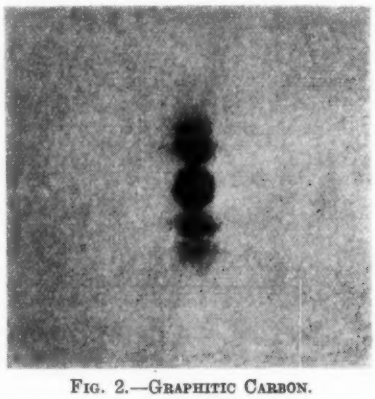

Fig. 2.—Graphitic Carbon.

If, with a pyrometer, they took an observation of metal containing 3 per cent. of carbon, and allowed the liquid metal to cool, it would be found that, as it began to solidify, it gave out heat, and there was a stoppage in the rate of cooling. This was due to an evolution of heat as the result of crystallisation. The point was explained by means of a salt and water analogy. When ultimately the whole mass solidified the eutectic was last to freeze, but if they exerted pressure just previous to final solidification they could squeeze out the eutectic.

The equilibrium diagram for the iron-carbon series was then explained, and the properties of the solid solution of iron and carbon, which, when examined under the microscope, is called austenite, were outlined. This solid solution may contain from 0 to about 2 per cent. of carbon.

Dealing with steel, Professor Turner emphasised the fact that steel could be defined as iron containing carbon in such proportions that at about 1,130 deg. C. the material consisted entirely of austenite. In other words there is no iron-iron-carbon eutectic in steel.

Cast-iron, said the lecturer, might be regarded when in the fluid state as white. Graphite was formed on cooling by the decomposition of the iron carbide. If the iron carbide decomposed near the melting-point of the cast-iron, coarse grained, large flake graphite was produced, and the metal

was weak and soft. When iron carbide was decomposed in solid iron at or about 900 deg. C. a very fine grained graphite was produced which was accompanied by considerable strength in grey cast-iron and with suitable properties in malleable cast-iron.

Fine-grained graphite had sometimes been called amorphous and a number of experiments had been carried out to find out the truth of this. They now knew that this fine grained carbon they all so much desired was just as much graphite as the coarse-grained, but was in a much finer state of division. An interesting experiment in this connection had been recently conducted by Kei Iokibé a Japanese investigator. Iokibé had said that graphite and temper carbon were sometimes assumed to be two different forms of carbon, crystalline and amorphous, but that the latter distinction was not based on any firm ground. It was possible, however, by means of the X-ray analysis to decide the question in a very simple manner, and in this way he had arrived at the conclusion that graphite and temper carbon were both the same in substance as natural graphite. The principle of the method consisted of taking a photograph of the diffraction figures produced by the action of the X-rays on minute crystals, whose orientations were uniformly distributed in all directions. Rods were made of natural graphite, coarse graphite from pig-iron, fine-grained graphite from pig-iron, and from sugar charcoal respectively. If the carbon rods were constituted of

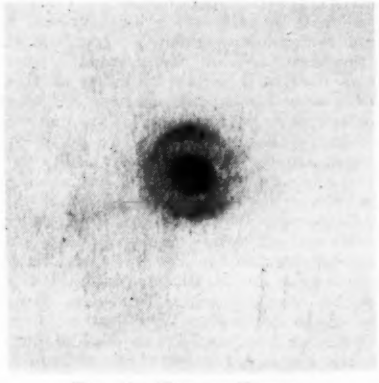

FIG. 3.—TEMPER CARBON.

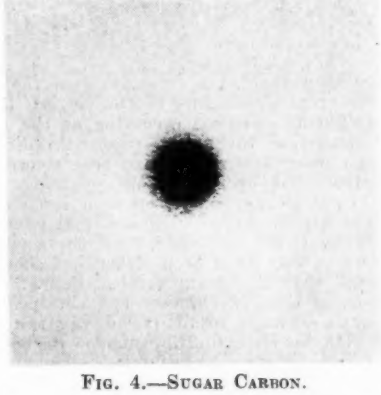

FIG. 4.—SUGAR CARBON.

minute crystals and the aperture was circular, diffraction rings were obtained, but if the rods were of an amorphous nature no rings were produced on the photographic plate. Professor Turner exhibited four photographs, shown in Figs. 1—4, which demonstrated that graphitic carbon, natural graphite, and temper carbon gave diffraction rings, while sugar charcoal showed no such effect. Hence it was quite clear that fine-grained carbon, obtained in cast-iron, was not amorphous, but crystalline. It was, in fact, as truly graphite as were the larger flakes.

MR. A. HARLEY, proposing a vote of thanks to the lecturer, said they would all agree that they could not understand cast-iron or steel properly until they had thoroughly mastered the cooling diagram. That was the basis of the whole subject, and he recommended everyone to prosecute their studies along those lines. Although it presented a great many difficulties they must go on and master it. It would be surprising how many problems, even foundry problems, would then solve themselves. The equilibrium diagram also when thoroughly mastered would enable them to make better castings.

LONDON BRANCH.

Discussion on Mr. Primrose's Paper on Heat Treatment of Copper Alloys.*

MR. W. LAMBERT said that the lecture this evening had appealed to him very much indeed. Mr. Primrose may not have published a very big book, but what matter he had published had been of very great value to the non-ferrous industry. Speaking of aluminium bronze, he (Mr. Lambert) looked forward to the time when the thermal treatment of this alloy would effect as great an improvement in its mechanical and other properties as had been the case in the thermal treatment of steel. Aluminium bronze lent itself to thermal treatment more perhaps than any other of the non-ferrous alloys. Even at the present time it was quite possible to cast from the same pot of metal castings which will give comparatively low tensile-strength, but which by very simple treatment could be converted into material from which a very good razor could be produced. He himself had seen a razor made from aluminium bronze, and he understood that it had proved fairly satisfactory in use. Manganese bronze had only been lightly touched upon by the author. Reference had been made to the duplex structure of such a bronze, but he would venture to point out that manganese bronze was not necessarily of a duplex structure, and manganese bronze of both the alpha structure and of the beta structure were commercial manufactures, and found uses for which their mechanical properties were particularly suited. He assumed that the tests shown upon the screen referred to manganese bronze of the alpha-plus-beta range only. With regard to the thermal treatment of manganese bronze, a considerable amount of work had been done although very little literature was available upon this subject, and such researches as have been carried out have been confined more particularly to the works laboratories of those firms specialising in the manufacture of this particular bronze. In connection with Admiralty gunmetal, he was of opinion that so far as those present who were connected with foundry practice, no one could go away from that meeting without a full knowledge of the procedure necessary to so treat test-bars of this material as to obtain tests of the nature of 22 to 26 tons break, and round about 40 per cent. elongation. The author had said he had not come across an elongation as high as 60 per cent. in his own practice. He (Mr. Lambert) had on one occasion tested an Admiralty gunmetal which gave 60 per cent. elongation, but it was produced more or less accidentally, and he would not be prepared to guarantee to make a bar to give such high elongation and at the same time comply with the chemical specification. With reference to the heat treatment of Admiralty gunmetal, if a casting or test-bar was defective on account of steam-holes, gassy metal, draws, etc., thermal treatment would not remedy such defects, and there was nothing left but to scrap the casting and remelt the metal. Mr. Primrose had published a Paper some time ago on the "Heat Treatment of Admiralty Gunmetal," in which he believed the author claimed to have saved a considerable number of castings by the closing up of the grain structure by thermal treatment, which castings would otherwise have been defective on account of porousness. As a result thereof, a certain foundry manager thought that such thermal treatment would be a panacea for all his troubles with this alloy, but after subjecting a number of castings to a process of heat treatment he was disappointed to find that the castings still leaked and had to be scrapped. These particular castings were badly drawn, and had large blowholes, and the grain structure was very large; thermal treatment would not help in such cases as that. One curve the

* See page 291, et seq.

author had shown on the screen which interested him very much, namely, the one referring to the wear-resisting properties of alloys cast or treated under varying conditions. No details were given as to how these tests were conducted or what was really meant. There was a considerable difference between abrasive wear when they had a rolling action as in gear wheels, and abrasive wear when the metal was presented to a rotating shaft or disc. The delta constituent was a hard constituent, and when selecting metals for a certain duty it was essential that a considerable portion of this hard constituent should segregate out in a uniform distribution throughout the mass. If they were going to subject such alloys to thermal treatment with a view of suppressing such segregation, or to ensure that the hard constituent should dissolve in the matrix the effect would be a hardening up of the matrix as a whole, but, so far as the wear-resisting properties were concerned, under certain conditions of service the material would give less length of duty than would be the case if the hard constituent was in a segregated form, always of course assuming that this hard constituent was sufficiently broken up and uniformly distributed throughout the mass. These bearing bronzes of the copper-tin series, having a segregated hard constituent, are comparable with the whitemetal alloys of the Babbitt metal class, in which the hard tin-antimony crystals and also the copper-tin crystals segregate out from a ground mass of either lead or tin or both, and have certain functions to perform. If it is only a question of securing high tests to satisfy Government or other inspectors irrespective of the duty the metal has to perform, then little true progress will be effected. He would have liked the author to have impressed more strongly upon the members the great significance of the vertical line in the equilibrium diagram occurring at the 10 per cent. content of tin in the copper-tin diagram. Quite a number test results had been shown upon the screen that evening, and apparently there was a want of agreement between some of the results obtained, and he suggested that it was not unlikely that the tin content of the particular alloys tested may have been either just short, on, or beyond that significant vertical line at the 10 per cent. of tin. He himself had obtained some very extraordinary results from Admiralty gunmetal. He was not going to condemn the 88—10—2 mixture as being a bad metal as so many founders do. If properly understood it was a good metal, and had done excellent service in the past. The fact that the 10 per cent. tin content was such a critical percentage has a great deal to do with the results that are obtainable, and the heat treatment of any such alloy included in the equilibrium diagram shown necessitated a considerable amount of study if one desired to obtain enhanced mechanical properties. The casting temperature, the rate of cooling—that is to say, whether the casting was allowed to cool out in the mould or shaken out while still quite hot—the bulk of the casting as a whole, thick and thin sections, were all factors having a very considerable bearing on the behaviour of the metal under service conditions, and also, of course, on the mechanical tests obtained on test-bars. He would like to ask the author whether he could enlighten them more on the mechanism by which so small a quantity as 0.3 per cent. of lead produced such uniformly good results under Sir John Dewance's supervision.

Mr. V. C. Faulkner said it had been found, with regard to the "faking" of steel, that if they stressed a steel test bar in the testing machine, then turned it up to size, and re-tested it later, much better results could be obtained, and he was wondering whether that would apply to brass. He congratulated the author on the book he had published on non-ferrous metals.

Mr. N. A. Naish, speaking with regard to brass, said that during the war he had been doing outside work for a firm making stampings for fuses, and every now and then there was a large consignment of failures. After eliminating possibilities of impurities it was still found that these failures occurred, and he had come to the conclusion that if the copper content of the brass varied between the limits of under 52 and over 59 there was undue cracking of the hot stampings of the fuses. Was it Mr. Primrose's opinion that this was a matter of chemical composition, or that a different temperature of stamping was necessary? With regard to gunmetal, gunmetal test-bars were difficult to get. The difficulty was the temperature of pouring. He suggested about 1,070 deg. C., but most foundrymen found that they got a distinct yellow core at the centre of a cylindrical test-piece at that temperature. Was it possible that that would be overcome by annealing at 750 deg. C.? As regards aluminium bronze, an interesting fact had come to his notice. There was a large casting, which was very weak and in which there were large crystals, owing to the effect of annealing, but where the casting had to be chilled and consequently quickly cooled, the metal was much sounder.

Mr. A. Wills said he had been struck by the wonderful results obtained by heat-treatment of non-ferrous metals, but he was also wondering whether that helped the practical foundryman, who had to deal with castings and not with test-pieces or test-bars. During the war he had had some experience of meeting Government tests in castings and in test-bars. He had succeeded very well with the test-bars, and also, he presumed, with the castings, but as a matter of fact the castings were very rarely tested at all, and were passed through on the test of the test-bars. The test-bars in many cases were cast under quite different conditions and under very much better conditions than the castings could possibly be. Consequently, he did not think there was very much value in the test-bar test. Years ago his firm had had to make some large valves, and the foreman thought it would be a very good thing to blow the cores out of the valves by quenching. This was done with a large number of them, and the cores were blown out cleanly, but on receipt by the customer it was found that many leaked. He suggested that to attempt to quench castings of various forms, with very light and very heavy parts, the strain set up by the quenching and sudden cooling would not cause more trouble than would be overcome by the annealing, and desired the author's opinion. Coming to aluminium-bronze, one trouble he had had was that in the first casting made it was found that the great contraction caused cracks. Another difficulty was in trying to get aluminium-bronze to pass a water-pressure test, and he would like the author to say whether heat treatment would improve, say, 10 per cent. or 8 per cent. aluminium-bronze alloy, in this direction. Dr. Carpenter and Dr. Edwards had carried out research on that very question, and had published a book on the casting of these valves for water pressure, and he thought, if he remembered rightly, that the best they could do was to get about 50 per cent. to stand the test. That was a very great point, and if the author had had any experience of that he would welcome further information. As to Admiralty gunmetal, this was a rotten metal, because it was specified by the Government to make valves to stand water-pressure, and in his opinion the normal 88/10/2 was not suitable for casting for high-pressure valves. He could give them a material containing other ingredients which was far better and would stand a far higher pressure. He supposed it was called a "rotten" material because of the difficulties experienced during the war in manufacturing pumps and valves of 88/10/2 material. Something took place in the separation of the constituents during casting. Little spots appearing on the skin of the casting, and probably they were the cause of the trouble in some cases. Some separation of the tin took place, which caused a leak. Again, there seemed to be trouble sometimes where the parts were thick and thin. He did not think that was due to contraction, because the contraction was very small in Admiralty gunmetal, but where the parts were thick and thin some strain was set up. He supposed the crystals were more open and caused leaking, but by adding a little lead or phosphor-copper or phosphor-tin it could be overcome. This introduced another difficulty. As soon as phosphor-tin was used difficulties arose in the machine shop; even with a quarter of 1 per cent. of phosphor-tin or phosphor-copper the difference in the hardness of the casting was noticeable. If they used lead they eased the work rather than made it harder, and he had found that a little lead, if only 0.5 per cent., or

less, made a superior casting, both as regards withstanding pressure and in appearance.

MR. T. D. ROBERTSON, whose experience had been almost entirely with iron and steel, said that he had been very interested in the lecture as it had struck him forcibly that although there were points of similarity between the behaviour of the copper alloys and of steels there were a number of fundamental differences exhibited. For example, phosphorus, the enemy of the steel maker, had a beneficial effect on the bronzes and the effect on the tensile strength of annealing or quenching steel was just the reverse of that shown for the copper alloys.

He would like to ask a question which was, perhaps, outside the exact scope of the Paper, and that was with regard to the electrical conductivity of copper-aluminium alloys. It had struck him that, as both copper and aluminium were good conductors of electricity, it might be that these alloys of copper and aluminium might have good properties from the point of view of electrical conductivity. He was interested in getting a casting which was sound and would withstand water pressure made in an alloy non-magnetic, and at the same time he desired that it should have as high an electrical conductivity as possible. He did not know whether some of the aluminium-bronzes would fulfil those demands, but he would be very interested if Mr. Primrose could give him some information on the subject.

The Author's Reply.

MR. PRIMROSE, in reply to the discussion, said he was rather surprised that Mr. Lambert had used the word "fake." When they annealed a steel casting they did not "fake" it; they made it right. He had been speaking of test-bars, but he should have pointed out that the test-bars were cast on to be heat-treated with, and then taken off actual castings. As a practical instance, his brother, Mr. H. S. Primrose, was associated with a firm which had been getting, with Admiralty gunmetal, 30 per cent. rejections of heavy castings. When they controlled the amount of tin by keeping it rather on the under side of 10 per cent., they got more of the alpha and less of the delta constituent. The delta shrank as it separated from the crystallites of primary alpha and left interspaces which intercommunicated, and water got through. If the castings were very unsound, annealing would make them worse, but if they were slightly unsound, due to the varying thickness in the sections, then they dissolved this delta constituent into the alpha, making it completely homogeneous and sound as regards water-pressure. They tested the actual casting from which the test-bar was taken. In one instance a casting which was leaking very badly was definitely rejected by an inspector, who put his rejection mark on it. It was subjected to proper heat-treatment and re-submitted, and he passed it unconditionally. When he was shown his rejection mark he asked how the casting had been faked. It was explained to him that it was not faked, but properly annealed and heat-treated, and when details were given he admitted that it was not a fake at all. As to Mr. Lambert's question with regard to the wear of bronzes, the curves shown from the Paper read at the New York meeting of the International Association for Testing Materials were the results of tests which consisted of taking small portions, about 25 mm. square and of suitable length, which were made to bear against a steel wheel rotated in an oil bath, and a delicate electrical instrument was used to measure the wear at one, two or four million revolutions of the steel wheel. Sir John Dewrance's 0.5 per cent. of lead had been considered important, not as a de-oxidiser of Admiralty gunmetal, because lead did not readily take up oxygen in molten gunmetal, but really as a cleanser. It might be that, as the lead, on the solidification of the gunmetal, never remained in alloy with it, but always separated as lead, it filled in the spaces, which were contraction cavities between the delta and the alpha, caused by the delta solidifying in a space too big for it. The taking away of the delta by the quenching was really a remarkable thing. They had found that the skin of a material in which delta was present needed perhaps four million revolutions before it wore out appreciably, but as soon as the skin came off, and they got down to the alpha and delta constituents, it wore away rapidly.

With reference to brasses, mentioned by Mr. Naish, the alloy he had shown for extrusion was approximately a 60/40 alloy, which could be used also for hot stamping. It must be worked hot, as it was outside the range of cold-working brasses, and undoubtedly the variation was due often to the loss of zinc by bad melting, and getting too much zinc either left in or burnt out, which gave that cracking effect. He had seen it frequently in fuse stampings, and undoubtedly it was the alteration of the constituents which gave that effect; it was the proportion of alpha and beta in the brass that regulated it so that it would crack or not, even at the suitable temperature for stamping, and he questioned if altering the temperature would do away with cracking in a brass of that nature, which was already brittle.

Gunmetal test-bars, as he had already explained, would, of course, only be annealed if they wanted to be honest, when the casting was also annealed. The annealing effect at once gave an enormous improvement if the bar were moderately sound. If it were not sound, annealing would make it worse. The core of yellow material inside that large casting of gunmetal was undoubtedly a source of weakness. This occurred not only in gunmetal but also in brass, and it was preferable, if making a test-bar, to cut down through the middle of a large section and take the test-bar somewhere nearer the side, closer to the skin, and get rid of that core.

As regards blowing out the cores of valves, referred to by Mr. Willis, the material should not have depreciated in strength provided they were not blown out too soon. They should not be blown out when red hot. When they came out of the boxes they should be allowed to lose their visible redness, and then quenched in a water trough, and the results would be good instead of bad.

MR. WILLIS said they were not red hot, but still they cracked.

MR. PRIMROSE replied that if not too hot they must have been of intricate design, with thick and thin parts, which set up differential contraction, because no matter how they quenched the castings the thick parts would retain the heat longer than the thin parts.

The question of annealing was, of course, not one which every foundryman wanted to do unless he had to meet such very high tests as, say, 900 or 1,000 lbs. internal water pressure. In such cases it undoubtedly made an improvement to anneal. In the case he had previously mentioned, in which there were 30 per cent. wasters of intricate casting, it took about six months to reduce this figure to 3 per cent. by controlling the composition, but as the result of annealing treatment it was reduced to 0.3 per cent. If they considered what that meant in money in a year the practical value of annealing would be obvious.

He had also been asked about aluminium bronzes, and Mr. Willis questioned if this quenching treatment would be useful in making them watertight. That, of course, was a point which had not been fully dealt with by any experimenter. He had no personal experience in the matter, but he certainly judged that once they got a moderately sound casting, and had allowed it to cool thoroughly—and this was important—the casting temperature of aluminium or aluminium alloys must be as low as possible, so that the solidification was quick and the subsequent cooling moderately so, the feeding heads must be very large, almost disproportionately large from the point of view of the iron founder, so that they did not get shrinkage—then the quenching after a suitable re-heating would be beneficial by closing the grain.

As to Admiralty gunmetal being a bad metal, it was only so to those who did not do it justice, and who did not try to understand its little idiosyncrasies. He would not say annealing would restore it always. They must not have any stewing of the metal in the melting pot. Too high a temperature of pouring was also inimical to good results, especially with heavy castings. With smaller ones they might be cast at a much higher temperature, but the heavier ones must be cast at a lower temperature even than that recommended by the American Bureau of Standards, and Dr.

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Carpenter in his recent Paper written in conjunction with Miss Elam. For a big, dry-sand casting they must get the temperature as low as it was possible for the metal to run. When they got oxide or gas holes, then it was a defective metal. Only the small shrinkage cavities in the castings which do not resist water pressure could be removed by the annealing treatment.

Interesting comparisons had been drawn by Mr. Robertson between ferrous and non-ferrous metals, but he certainly would repeat that it was not really "faking" in either steel or gun-metal to give it the proper heat-treatment. As to the electrical conductivity of copper-aluminium alloys, it was a remarkable fact that when they took two good conductors and mixed them in an alloy, whenever they got two constituents so dissimilar as alpha and beta, they at once dropped the electrical conductivity enormously. They might think of an analogy in the copper-zinc series, where, as they added more zinc, the electrical conductivity of the copper fell slowly until they reached about 20 per cent., and then it dropped enormously. He was speaking from the structural point of view, and that was what controlled the current conduction. The purer the metal, as a rule, the higher its conductivity. Any impurity, slowly at first and rapidly later, reduced that conductivity, and if Mr. Robertson wanted a sound casting of non-magnetic properties and higher resistance to water pressure, he thought it might be advisable to try what was called "electrical mixture." This was very nearly pure copper, but pure copper, when cast, was usually full of oxide, as copper oxidised readily and had the bad property of dissolving its own oxide. The addition of a small proportion of zinc, usually in the form of yellow brass, with a small percentage of tin, would give a remarkably sound, high tensile, very close grain and very high electrical conductivity metal. It gave anything up to 15 or 16 tons tensile, and 30 or 40 per cent. elongation.

A vote of thanks was accorded to the lecturer, who suitably replied.

SCOTTISH BRANCH.

At a meeting held at Glasgow on March 26, Mr. Fraser (Branch-President) in the chair, the following gentlemen were elected to the various offices for the session 1920-1921:—President, H. Hodgert; Sen. Vice-President, A. Lawrie; Jun. Vice-President, J. Logan.

Members of Council.—A. Ure (Glasgow), T. Mayer (Dumbarton), A. Y. Wilson (Coatbridge), G. Mackay (Paisley), A. Mearns (Barrhead), A. Cree (Glasgow), J. Affleck (Cathcart), J. Gardner (Kilmarnock), R. Robertson (Falkirk), J. Cameron (Kirkintilloch).

Representatives to the General Council.—H. Hodgert, J. Cameron, W. H. Bound.

Mr. W. H. Bound, 5, Midlothian Drive, Shawlands, Glasgow, was elected hon. secretary.

The following report was submitted to the meeting:—

Report of Council.

The Council have pleasure in submitting to the meeting their tenth annual report. In doing so they wish to state that the Scottish Branch have to place on record two outstanding events which occurred during the past session. The first is that one of our members, a past-President of this Branch, Mr. Riddell, is President of the parent Association. The second is that the annual conference of the Institution was held at Glasgow last July.

With reference to the former, the Council consider that the election of Mr. Riddell as President of the Institution is not only an honour to the Scottish Branch, but a personal distinction to an eminent foundryman. The arrangements for the Conference were carried out by this Branch, and the Council have the pleasure in recording that this event was highly successful and thoroughly enjoyed by all the visitors.

Reverting to purely Branch business, the Council have to report the successful inauguration of a sub-section at Falkirk. The programme of lectures for the session were of a high order.

The membership of the Branch is now 322, showing an increase of 29 on last year's figures; this is an indication that the interest in the Branch is being well maintained. The syllabus was again issued in book form by the Branch.

The Council have pleasure in announcing that they have renewed the agreements with the West of Scotland Iron and Steel Institute, also with the Foremen and Draughtsmen's Association, which enables members to have the privilege of attending the meeting of these Associations.

Mr. McFarlane, who was Secretary of the Branch for some years, was forced to resign owing to increasing calls upon his time. The Council, in order to show their appreciation of his work, instituted a Testimonial Fund, which was well supported by the members. Seven Council meetings were held during the session, and the work of the Branch has been carried on efficiently and smoothly.

The Council have again to place on record their indebtedness to the Governors of the Royal Technical College, Glasgow, for the facilities offered to the Branch for their meetings.

Further, it is also desired to thank Messrs. Wm. Jacks & Company, Limited, 19, St. Vincent Place, for their excellent facilities and arrangements for the Council meetings.

Mr. Fraser, the retiring President, then delivered his valedictory address. He stated that the position which he was about to relinquish, namely, President of the Scottish Branch of the Institute of British Foundrymen, was one of the highest honours to which a Scottish foundryman could achieve, and he could assure the members that he appreciated the honour of having filled such a high office.

He would like to take this opportunity of thanking the office-bearers and the members for the support which had been extended to him during his term of office. At the same time he wished Mr. Hodgert, the new President, every success.

Mr. Hodgert, on assuming office, said that during his term of office it would be his aim to try and maintain the very high standard which had been set by his predecessors. He then referred to the excellent work which had been accomplished by Mr. Fraser, the retiring President. Mr. Fraser had performed the duties associated with his office to the entire satisfaction of the Association, and he assured Mr. Fraser that the services which he had rendered were appreciated to the highest degree. The next business on the agenda was the presentation of a gold watch to Mr. John McFarlane, the late Hon. Secretary of the Scottish Branch, and a gold brooch to Mrs. McFarlane. Mr. Riddell, President of the Institution, made the presentation.

Mr. J. Cameron then read a paper on Semi Steel.

BIRMINGHAM BRANCH.

Election of Officers.

The annual meeting was held at Birmingham on the 2nd inst., when the following officers were elected for the ensuing year:—

President.—H. Field (Willenhall).

Vice-Presidents.—C. Flavell (West Bromwich), A. Wardell (Wolverhampton).

Secretary.—Mr. F. B. Holberry (West Bromwich).

Council.—F. Johnson, M.Sc., J. Tyson, H. Winterton, A. Parsons, C. B. Pugh, Thos. Vickers, C.E., F. G. Starr, J. B. Johnson, J. Wilkinson.

Delegates to the Institution Council.—H. Winterton, Thos. Vickers.

Auditors.—H. Winterton, Thos. Vickers.

The annual report showed that the Branch is in a very flourishing condition, the membership being 206.

Queries Answered.

The Use of Cast Iron Borings in the Cupola.

In answer to "Omo's" inquiry, which we gave in our last issue, we would advise that the borings should be briquetted before use. Several machines are on the market for this purpose, and details of one specially adapted for this purpose were given in our issue of January 6. In this article it was suggested that the swarf should be mixed with 5 per cent. of slaked lime and 5 per cent. of water before briquetting.

Trade Talk.

MUNTZ'S METAL COMPANY, LIMITED, have removed their London offices to 126, Bishopsgate, E.C.2.

THE CENTRAL IRON & METAL COMPANY, LIMITED, have removed their head office to 75, Victoria Street, London, S.W.1.

DURING the next official year over 967 lakhs of rupees will be spent by the Indian Government on railway rolling stock.

THE Welsh Engineers' and Founders' Association have served notices on their employés for a reduction of 12s. 6d. per week.

THE CALDERBANK STEEL WORKS, of James Dunlop & Company, Limited, near Airdrie, resumed work last week after about a week's stoppage.

NORTONS (TIVIDALE), LIMITED, Tipton, have appointed Mr. A. Wallis Bainbridge, 63, Queen Victoria Street, London, E.C.4, as their agent for London.

THE shipbuilding industry on the Wear is in a very depressed condition, as is evidenced by the fact that there was only one steamer launched during the month of March.

THE imports of foreign iron ore at the Senhouse Dock at Maryport for the quarter ending March 31 have been 21,500 tons, compared with 29,800 tons for the previous three months.

THE PENARTH PONTOON SLIPWAY & SHIP REPAIRING COMPANY, LIMITED, have acquired a controlling interest in Hodges & Company, Limited, engineers and ship repairers, Barry Dock.

THE official returns of iron and steel shipments from the port of Middlesbrough for March show that the pig-iron exports fell to only 4,370 tons—the lowest recorded in the history of the trade.

Two Merseyside firms, one ship repairing and the other electrical, contemplate opening branches at Antwerp in order to secure a share of the work going there owing to labour troubles in this country.

THE MERSEY ENGINE WORKS, Sefton Street, Liverpool, which have hitherto carried out most of the ship-repair work for the Elder Dempster Company, have been taken over by Harland & Wolff, Limited.

A CHINESE banking group at Pekin invites tenders for the following locomotives:—Thirty Prairie, two Mikado, three Pacific, six English types; also 200 all-steel covered wagons, 40 metric tons; 100 all-steel open wagons, same capacity.

IT is understood that, by an agreement between the Federation of Civil Engineers' Contractors and the men's unions, wages have been reduced on Tyneside by 3d. an hour, and that the hours to be worked will be 49½ per week, instead of 47 heretofore.

THE Engineering Employers' Federation announce that they intend to introduce a general reduction in the wages paid by federated firms, the basis of which is 6s. a week, on the earnings of time workers and 15 per cent. on those of piece workers.

THE Chartered Institute of Patent Agents is asking a postcard vote of registered patent agents upon a proposal to apply to the Board of Trade to make an order under Section 21 of the Patent Agents' Rules, 1920, to stop all advertising by such agents.

THE Clyde shipbuilding output in March amounted to 30 vessels, totalling 55,225 tons. The first three months' productivity of 153,854 tons is a record for the first quarter of a year, but the outlook is not promising.

THE Sheffield branch office of Herbert Morris, Limited, Loughborough, has been removed from Cairns Chambers, St. James Street, to more commodious premises, etc.: Montgomery Chambers, Hartshead, Sheffield.

THE American Government has 400,000 tons of steel on hand, and has received from an unnamed foreign Government an offer for it at a price higher than the market quotation. It is stated the Government will sell if its terms and conditions are met.

BOND and debenture holders of the British-American Nickel Corporation have approved a plan of reorganisation. Of the $5,720,000 bonds represented holders of $5,347,000 voted in favour of the resolutions submitted to the meeting.

DR. AITCHISON, in a paper on "Alloy Steels for Large Forgings," which was read before the Staffordshire Iron and Steel Institute, on March 10, draws attention to the types of steels which can be utilised for forgings where a higher tensile strength is required.

A CONFERENCE between the employers in the file industry and the representatives of the workmen was held in Birmingham last week, when the proposal of the employers for a reduction in wages of 15 per cent. on existing piece rates was considered. It was decided to hold a further meeting.

THE adjourned conference between the Shipbuilding Employers' Federation and the Amalgamated Union of Shipbuilders, Engineers and Constructional Workers on the question of the standard ship cycle of wage advances and consequential increases is to be resumed at Carlisle on April 19.

THE film exhibition recently given by the Mond Nickel Company, Limited, of the many and diverse uses of nickel was both interesting and instructive, the pictures illustrating every process from winning the ore at the well-known Sudbury district in the Province of Ontario to its shipment for export.

ADDRESSING the Industrial League and Council in London on "Industrial Unrest as a Factor in Progress," Mr. John Baker, of the Iron and Steel Trades Federation, referring to conditions in the steel and iron industry, said he did not believe the world could afford to continue to pay the steel workers what they were being paid to-day.

SPEAKING at the annual meeting of the South Wales Association of Iron, Steel, Tinplate and Metal Merchants, at Swansea, Mr. C. Briggs, who was re-elected president, expressed doubt as to the effect of the German Reparations Recovery Bill, and remarked that the immediate effect was that the Germans refused to sell except for cash.

ACCORDING to Mr. A. W. Tait, C.B.E., chairman of the British Aluminium Company, Limited, reductions have been made in the price of ingot and manufactured metal since the beginning of the year in order to encourage demand. The immediate future is, however, somewhat uncertain, and the industry will necessarily take time to get back to normal.

A PROTRACTED investigation of labour and production conditions in the engineering and shipbuilding trades is to be commenced within the next few weeks by a committee representative of the employers and workers. The representatives of the employers have been chosen by the Employers' Federations and of the workers by the various trade unions concerned.

THE Earl of Harrowby, speaking at the annual meeting of Robert Heath & Low Moor, Limited, said, in the course of his speech: "I should like to remark that the shareholders of the company receive a gross sum of £100,000, or net of £70,000, against wages paid of over £2,000,000, so that the amount received by the shareholders represents 3½ per cent. only of the total sum paid in wages."

THE annual dinner of the Sheffield and District Iron, Steel, Metal and Waste Trades Association was held on March 30. Mr. W. Waterhouse, the president, presided, and was supported by, amongst others, Mr. R. Jackson, of Manchester, Mr. T. W. Casey, M.P., Mr. H. N. Crowther, Leeds (president of the North of England Association), Captain T. Morgan, Pontypridd, and Mr. H. Morris.

LORD INVERFORTH, at an informal gathering at his residence, Arnos Grove, on the 2nd inst., was presented with a life-size portrait of himself painted by Mr. R. G. Eves. The presentation was made by Sir James Currie, on behalf of the business men who had helped Lord Inverforth in his work as Minister of Munitions and previously as Surveyor-General of Supply at the War Office.

AT the March meeting of the Institution of Engineers and Shipbuilders in Scotland held on Tuesday evening in the rooms in Glasgow, Mr. R. D. Moore presiding, the following nominations by the council for office-bearers for next session were submitted:—President, Mr. Harold K. Yarrow; vice-presidents, Messrs. J. Craig, M. E. Denny, J. Garrick, J. B. Hutchison, Hugh Reid, LL.D., and A. B. Allan (associate).

THE monthly meeting of the Newcastle and District Association of Foremen Engineers and Draughtsmen was held on the 2nd inst., at Sunderland, Mr. James Meredith presiding. The following were elected members:—Mr. W. Douglas, of Messrs. Smith's Dock Company; Mr. J. W. Dinning, of the winch department of Messrs. Clark, Chapman & Company; Mr. William Saddler, of the marine engine department, Elswick Works; and Mr. Edward Choleron, of the brass department, Elswick Works.

MR. G. TAYLOR, of the Taylor File and Tool Company, Leeds, who lectured on the 5th inst. before the Sheffield Association of Metallurgists and Metallurgical Chemists, emphasised the necessity of making the production of files as automatic as possible, in order that consistent results might be obtained. He said that under present conditions it was impossible to obtain uniformity in file teeth by either hand or machine cutting. This was due to variation in the hardness of the blanks and variations in the grinding and whetting of the chisels.

THE STEEL INGOT MAKERS' ASSOCIATION and the North of England Iron and Steel Manufacturers' Association have asked the affected trade unions for an early conference to "consider the adjustment of war wages advances and of war bonuses" secured by certain sections of workers engaged in the industry.

THE reconstruction of the Buckingham Palace Hotel, and its conversion into business premises for Nobel Industries, Limited, is nearing completion, and in future the building will be known as Nobel House. It was recently announced that Nobel's Explosives Company, Limited, of Glasgow, a constituent company of Nobel Industries, Limited, had decided to dispose of their

Glasgow offices in view of the coming move of their staff to London.

The trade will learn with great interest that the Prince of Wales has given permission for the National Portrait Fund to publish "The Prince of Wales Calendar for 1922" in aid of all those men of the three Fighting Services, irrespective of rank, who defended their Empire with self-sacrificing loyalty and devotion, and now find themselves in want. The calendar is of beautiful design and mounted upon it is a specially selected unpublished portrait of the Prince reproduced in English photogravure. It is further suggested that before ordering their usual supplies of calendars for 1922, all firms should make a point of communicating with the Hon. Secretary, The National Portrait Fund, 13, Duke Street, St. James's, London, S.W.1, who will willingly send samples and full particulars.

Company News.

Baltic Coal & Shipping Company, Limited.—Capital £20,000 in £1 shares (18,000 preference)

Henry Hunt, Limited, general engineers.—Capital £5,000 in £1 shares. Registered office: 40, Bagot Street, Birmingham.

Caffin & Company, Limited, engineers. — Capital £25,000 in £1 shares. Registered office: 25, Craven Street, Strand, W.C.

British Engine, Boiler, & Electrical Insurance Company, Limited. — Final dividend, 8s. 6d.; bonus, 4s. per share, making 20s. per share for year.

Smith & McLean, Limited.—Profit, £68,831; available £43,485: ordinary dividend, 10 per cent. per annum, free of tax; carry forward, £19,110.

Ransomes & Rapier, Limited.—Disposable balance, £32,806; ordinary dividend, 8 per cent., tax free; reserve (making £55,661), £5,000; carried forward, £17,99[illegible].

Associated Trading & Engineering Company, Limited.—Capital £5,000 in 4,900 ord. of £1 and 2,000 defd. of 1s. Registered office: 23, Great Queen Street, Kingsway, W.C.

Weardale Lead Company, Limited.—Directors unable to recommend payment of interim dividend on account of present financial year, the first half of which expired on March 31.

All British Tool & Steel Company, Limited.—Capital £15,000 in £1 shares. Permanent directors: E. C. Strong (chairman), H. C. Strong, and E. Cecil Strong. Secretary: H. Strong. Registered office: Prudential Buildings, Pinstone Street, Sheffield.

Browett, Lindley & Company, Limited.—Debenture interest, £2,399; depreciation, £4,292; net profit, £8,694; brought forward, £9,484; preference dividend, 6 per cent.; further dividend, 6 per cent. on preference on account of arrears, £6,000; ordinary dividend, 8 per cent., £3,000; carried forward, £9,178.

Penarth Pontoon, Slipway & Ship Repairing Company, Limited. — Profit, £15,824; brought forward, £5,013; interest on debentures, £1,620; two mortgage debentures paid off, £500; general reserve, £5,000; general depreciation, £6,175; final dividend, 5 per cent., making 10 per cent., less tax; carry forward, £2,451.

Elliott Drop Stamping Company, Limited.—Capital £5,000 in £1 shares (1,000 preference, 3,990 ordinary, and 10 founders'), to take over the business carried on by P. Elliott and A. Dalton as the Sheffield Die Sinking Company and the Elliott Drop Stamping Company, at Sheffield. Directors: P. Elliott (permanent managing director and chairman) and A. Dalton.

Globe & Simpson, Limited. — Capital £2[illegible] shares, to take over the business of electrical equipment engineers carried on by R. C. Globe and T. W. Globe at Burgess Street, Barker's Pool, Sheffield, as Globe & Simpson. Directors: R. C. Globe, T. W. Globe, and S. Higgs. Secretary: J. W. Collier. Registered office: 32, Burgess Street, Barker's Pool, Sheffield.

Deaths

Mr. R. M'Connel, ironfounder, of Port Dundas, died at Ardvan, Dunoon, on March 28, aged 78 years.

Mr. P. G. Barnsley, Junr., of the firm of Messrs. Barnsley & Sons, iron founders, Netherton, died recently at his residence, Church Road, Netherton, Dudley, at the age of 38 years. He was the son of Mr. J. W. Barnsley, J.P.

The death has occurred, at the advanced age of 90 years, of Mr. William Brough, a native of Gateshead, at Barnstaple, North Devon. The late Mr. Brough, who was a brother of Mr. Edward Brough, of Ashfield Tower, Gosforth, was an engineer, and served his time with Messrs. Clarke, Chapman & Company, Limited, Gateshead, before he left the North, some 60 years ago.

Gazette.

Murray Foundry Company, Limited (in voluntary liquidation).—Claims to D. F. Middlemiss, 6 and 7, Coleman Street, E.C., C.A., liquidator, by May 14.

Oldbury Rolling Mills, Limited.—Resolved March 1, confirmed March 17:—That the company be wound up voluntarily. Mr. C. Pittman, 26, King Street, Guildhall, E.C., C.A., liquidator. All liabilities are being fully discharged.

The partnership heretofore subsisting between Arthur Edwin Pratt and David Adams, trading as Arthur E. Pratt & Company, 5, Chancery Lane, W.C., engineers and metallurgists, has been dissolved. Debts by Mr. A. E. Pratt, who continues the business.

Trading as the Tower Foundry Company, the partnership between John Hodgkins, Alfred Savage, John Savage, and Angelina Savage, 1, Billhay Lane, West Bromwich, has been dissolved, January 29. Debts by Mr. J. Hodgkins, who continues the business.

Coventry Simplex Engines, Limited.—A resolution has been passed that the company be wound up voluntarily. Mr. E. N. Humphreys, Old Bank Buildings, Chester, and Mr. G. G. Poppleton, 26, Corporation Street, Birmingham, C.A., have been appointed liquidators.

Trading as the Press Tool and Metal Stamping Company, the partnership between Oliver Montgomery, Arthur Turner, and Herbert Evans, Burnaby Street, Wallasey, press tool and metal stampers, has been dissolved. Debts by Messrs. O. Montgomery and A. Turner.

Stafford Associated Engineering Company, Limited.—Petition presented March 30 by Aigburth Motor and Garage Company, Limited, Liverpool. Hearing, Royal Courts of Justice, Strand, April 12. Agents, Messrs. Rutherford & Company, 48, Cannon Street, E.C., solicitors.

The partnership hitherto subsisting between Frederick Fothergill Adamson and Richard Sanderson McLean, trading as Adamson and McLean, 1, Queen's Crescent, and 12, Tintern Street, Sunderland, engineers, has been dissolved. Debts by F. F. Adamson, who continues the business under that name.

Crawford Foundry Company, Limited.—On a petition presented, March 15, by Elton, Levy & Company, Granville Park Works, Brettenham Road, Edmonton, the above company is in course of liquidation. Hearing, Royal Courts of Justice, Strand, April 12. Messrs. Morley, Shirreff & Company, 53, Gresham House, E.C., solicitors.

West Suburban Tool and Engineering Works, Limited, Hanwell, W.—Resolved March 14, confirmed March 29:—That the company be wound up voluntarily. Mr. O. L. Thomson, 47, Lincoln's Inn Fields, W.C., appointed liquidator. Meeting of creditors, Messrs. H. E. and W. Bury's, 47, Lincoln's Inn Fields, W.C., April 14 at 3.

At the expiration of three months the names of the undermentioned companies will, unless cause is shown to the contrary, be struck off the Register of Joint Stock Companies, and the companies will be dissolved:—Hercluum Metal Company, Limited; Inshaw Seamless Iron & Steel Tubes, Limited; Interchangeable Brake Block Company, Limited; and the Thames Smelting & Refining Company, Limited.

Personal.

Mr. T. H. Nash, secretary of Steel, Peech & Tozer, Limited, The Ickles, Rotherham, has been the recipient of a presentation on his retirement after 45 years' service.

Mr. J. T. Rubery, founder of the firm of Rubery, Owen & Company, Darlaston, who died on December 18, has left £18,671 gross and £17,867 net.

The late Mr. S. Clarke, metal merchant, of Birmingham, left £3,016.

The late Mr. J. Attwood, engineer, of Stourbridge, left £8,687.

Mr. H. B. Sandford has been elected a director of Hadfields, Limited.

The late Mr. W. A. Drake, chairman of Drakes, Limited, Ovenden, left £38,294.

Mr. R. McGregor, chief mechanical engineer to J. G. White & Company, Limited, has been appointed engineer and manager to Clayton & Shuttleworth, Limited.

The following remark occurs in a General Report on the Economic Situation of Denmark at the close of the year 1920 by Mr. R. M. Turner, published by the Department of Overseas Trade: "It is of interest to note that an iron foundry is in course of construction at Copenhagen. In this only scrap iron will be treated, which in former years has been exported."

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Pneumatic, Hydraulic, Jar Ramming, & Hand Power.

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Fitted with self-adjusting Rammer Head which accommodates itself to any varying depth of pattern.

OVER 50 COMPLETE MOULDS PER HOUR HAVE BEEN PRODUCED

ON THIS MACHINE WITH UNSKILLED LABOUR.

One of many that we have installed in various Munition Work Centres.

JAMES EVANS & CO., BRITANNIA WORKS, BLACKFRIARS, MANCHESTER.

IRON AND STEEL MARKETS.

Pig-Iron.

Concurrent with the complete suspension of the colliery industry of the country, pig-iron markets have ceased activity, and business, previously in a far from satisfactory condition, is now at an absolute standstill. Blast-furnace plants in all districts are either damped down or blown out, and production for the time being is virtually idle, as, it may be added, is the demand for pig-iron. As illustrative of the latter condition it may be noted that last month the exports of pig-iron from Middlesbrough were actually balanced by the imports—an event absolutely unprecedented in the history of the trade, but equally pronounced in the case of home consumers and overseas demand At last week's Tees-side market, probably with a view to counteracting the Continental competition lately experienced, it was announced that a further revision of prices had been decided upon by the Cleveland ironmasters, making an additional reduction of 30s. per ton for all brands of pig, with 120s. per ton the maximum for standard foundry quality. The last reduction was no less than 45s. per ton, and as compared with the price at the beginning of the year, Cleveland pig-iron has now fallen no less than five guineas per ton. With a free market for the export trade, the premium of 5s. per ton hitherto demanded has quickly disappeared, and makers are willing to sell at the home price irrespective of destination, quotations being as follows:—No. 1 and silicious, 125s. per ton; No. 3 Cleveland G.M.B., 120s.; No. 4 foundry, 119s.; No. 4 forge, and mottled, 117s. 6d.; and white iron, 115s. per ton.

East Coast hematite smelters adhere to the agreement to keep the home price at 180s. per ton, but it is reported that 20s. per ton less will be accepted for export, the latter branch of the trade being free from price control. So far as North Lancashire is concerned there is only the one furnace at Ulverston blowing, and that is on easy blast, and the men are now engaged only from day to day. Its continuance in operation will depend now on the position of affairs in the coal trade.

Ore.

Conditions in the foreign ore market disclose little change from the stagnation previously reported, deliveries on Tees-side being practically suspended, while prices may be regarded as nominal only. Best rubio ore is still quoted at 37s. 6d. per ton c.i.f. Tees, but there has been no business transacted lately to test the market. In North Lancashire, with so many furnaces out of blast, the demand for iron-ore is very small and only one pit is working.

Scrap.

Business in this class of raw material is everywhere restricted by the prevailing industrial conditions, and very few transactions are reported in the various markets. Many of the largest consumers among ironfounders are already fairly well stocked, and are consequently off the market, while the recent drastic reductions in pig-iron prices have naturally induced some reconsideration of present scrap metal values. Heavy ordinary steel scrap is now a drug on the market, and even the best textile machinery qualities fail to elicit offers from buyers. Equally difficult of disposal are mixed wrought iron and steel metal, and similar conditions apply in the case of heavy cast scrap in large pieces now offered in South Wales at 30s. to 80s.

Tinplates.

An unexpected result of the present labour disturbance has been the revival of inquiries for prompt parcels in the tinplate market on consumers' account, possibly stimulated by a desire to have supplies in hand in view of future contingencies. Values in consequence have stiffened to some extent, coke tins in I.C., 14 x 20, having been done at 25s. for primes, and other lines in proportion. There is very little doing for forward delivery, makers' prices of 28s. to 30s. failing to tempt buyers. With regard to wasters, 18s. 6d. has been bid for C.W., 14 x 20; 36s. 6d. for C.W., 28 x 20, and up to 15s. net, f.o.t. at works, for C.W., 14 x 18¾, the latter size now becoming rather scarce. Terneplates are in quiet demand, a small business being reported at round 27s. basis net, f.o.t. works, for April-May. Stock parcels can, however, be bought at 1s. to 2s a box less money.

Steel.

The crisis through which the country is passing has naturally accentuated the depression already experienced in all departments of the steel trade, and for the moment the outlook is distinctly cheerless, many of the principal works having closed down since Easter with little prospect of an early renewal of activity. An exception may, however, be made perhaps in the case of makers of farm, field and garden tools and appliances, although here also, the seasonal demand is reported below the average of the last few years. Arrears of work at the rolling mills are comparatively light, and there is very little for the forges to do, but railway material departments are fairly well employed, although the orders placed are all very much smaller than was customary owing to high prices. In other departments—springs and tyres—overtime and Sunday working are being continued by some firms. Engineering departments are very quiet, and some of the wire firms are not working, so few are orders, while makers of files, saws, pincers, hammers, turnscrews, etc., are not quite so busy as they were.

Finished Iron.

Throughout South Staffordshire there has been almost a total cessation of work in all branches of the finished iron trade, many of the principal establishments having suspended operations without prospect of reopening until the termination of the present trouble in the coal fields. This decision of the manufacturers may, however, result in some accumulation of orders in the interval, for at present, at all events, there are few specifications in hand in any branch of the trade. Demand for finished material in all sections of the industry is almost at a standstill, and makers in the more favoured departments would have some difficulty in providing employment for the workpeople, even if there were no strike in progress Scotch iron bars have been reduced to £19

Metals.

Copper.—The more promising outlook in the labour situation influenced a better feeling at the opening market of the week for standard copper, and although there was an absence of consumptive demand the tone throughout was steady. The low levels of value now prevailing, however, has had an adverse effect upon production, and many of the largest American copper mine interests are closing down until an improved demand justifies a renewal of operations. Quotations in Monday's markets closed firm with an advance of 7s. 6d. and 10s. respectively for cash and three months, but very little actual business was passing. Closing prices:—Cash: Wednesday, £68 15s.; Thursday, £69; Friday, £68 17s. 6d.; Monday, £69 5s.; Tuesday, £69. Three Months: Wednesday, £68 10s.; Thursday, £68 15s.; Friday, £68 15s.; Monday, £69 5s.; Tuesday, £69 2s. 6d

Tin.—Eastern cables advising a fairly substantial advance in values stimulated a corresponding tendency on this side, and the markets opened with a fairly good demand, while holders of tin were more inclined to act with reserve. Consequently prices marked an advance in values for both positions, April being done at £162; May, £165 to 10s. better, closing at the first-named figure; June, £162 10s. to £165 10s.; July, £164 15s. English ingots were improved at £159 to £160 and "Lamb and Flag" cash at £164 10s. The weekly return of stocks in London warehouses show a decrease of 393 tons at 4,156 tons, and Liverpool 51 tons increase at 2,434. Closing prices:—Cash: Wednesday, £154 10s.; Thursday, £158 10s.; Friday, £159 10s. Monday, £163; Tuesday, £161 10s. Three Months: Wednesday, £157 15s.; Thursday, £161 10s.; Friday, £163; Monday, £165; Tuesday, £165.

Spelter.—The hardening tendency in this metal previously reported continues, and at the week's opening market sellers were again reserved, near dates and forward business being done at 7s. 6d. and 12s. 6d. advances respectively. May deliveries were marked at £26 5s., and August at £27 2s. 6d., closing firm on the settlement basis of £25 15s. Ordinary brands, prompt:—Closing prices: Wednesday, £24 15s.; Thursday, £24 15s.; Friday, £25 17s. 6d.; Monday, £26; Tuesday, £26.

Lead.—Consumer's inquiries on an increasing scale developed a further hardening in prices for foreign lead, good soft pig making advances of from 7s. 6d. to 12s. 6d., with April selling £20 10s. to £20 12s. 6d., June £21 5s., and English 10s. dearer, closing at £22 5s.

SIEMENS' STEEL PROCESS

BOILER, SHIP and BRIDGE PLATES, etc. ANGLES and all forms of Sectional Bars. TYRES and AXLES to all requirements. CASTINGS of all kinds and of Largest Sizes. FORGINGS of every description. BILLETS, BLOOMS, RAILS.

SPECIAL STEEL FOR CONSTRUCTIVE PURPOSES.

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Sole Makers:

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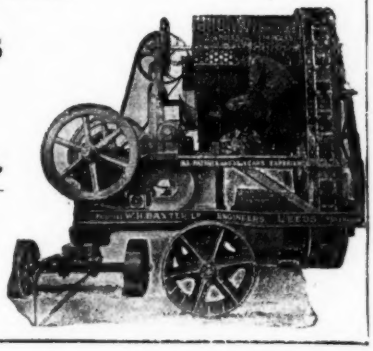

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For Fuel Economy, Efficient Control, Long Life of Pots.

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SPECIALITIES:—

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WEEKLY PRICE CURRENT.

COPPER.

	£ s. d.
Standard cash	69/0/0—69/2/6
Three months	69/2/6—69/5/0
Electrolytic	72 10 0
Tough	69 15 0
Best selected	70 0 0
Sheets	116 0 0
India	116 0 0
Wire bars	73 5 0
Do. May	73 5 0
Do. June	73 5 0
Ingot bars	72 10 0
H.C. wire rods	79 10 0
Off. aver. cash, Mar.	67 13 3⅜
Do. 3 mths., Mar.	67 7 0⅜
Do. Settlement Mar.	67 12 8⅜
Do. Electro, Mar.	71 15 0
Do. B.S., Mar.	69 18 10⅜
Aver. spot, copper, Mar.	67 12 7½
Do. Electro, Mar.	72 6 2½
Solid drawn tubes	15½d.
Brazed tubes	15½d.
Wire	12d.
Yellow metal rods	8¾d.
Do. 4x4 Squares	10¾d.
Do. 4x3 Sheets	10¾d.

BRASS.

Solid drawn tubes	13¾d.
Brazed tubes	16¾d.
Rods	12¼d.
Sheets to 10 w.g.	11⅝d.
Wire	11⅜d.
Rolled metal	11¼d.

TIN.

Standard cash	161/10—162/0
Three Months	165/0—165/5
English	160 0 0
Bars	162 0 0
Chinese	156 5 0
Straits	171 5 0
Australian	170 0 0
Eastern	164 10 0
Banca	178 5 0
Off. aver., cash, Mar.	156 4 7
Do. 3 mths., Mar	159 13 1½
Do. Sttlment., Mar.	156 2 1½
Aver. spot, Mar.	156 0 3

SPELTER.

Ordinary	26 0 0
Remelted	21 10 0
Hard	17 0 0
Electro 99.9	33 10 0
English	28 10 0
India	19 10 0
Prime Western	26 10 0
Zinc dust	52 10 0
Zinc ashes	6 0 0
Off. aver., Mar.	25 10 5
Aver., spot, Mar.	25 1 6½

LEAD.

Soft foreign ppt	20 15 0
English	22 5 0
Off. average, Mar.	19 2 9½
Average spot, Mar.	18 18 2½

ZINC SHEETS.

Zinc sheets, spot	36 0 0
Do. V.M. ex. whf	37 0 0
Do. ppt., f.o.b., N.Y.	—
Dutch	35 0 0
Boiler plates	33 0 0
Battery plates	32 10 0

ANTIMONY.

English regulus	37 5 0
Special brands	42 0 0
Chinese	24 0 0
Crude	19 0 0

QUICKSILVER.

Quicksilver	12 10 0

FERRO-ALLOYS AND STEEL-MAKING METALS.

Ferro-silicon—	
45/50%	17 10 0
75%	25 0 0
Ferro-vanadium—	
35/40%	25/- lb. va.
Ferro-molybdenum—	
70/80%	10/- lb. mo.
Ferro-titanium—	
23/25%, carbonless	1/6 lb.
Ferro-phosphorus, 20/23%,	£32
Ferro-tungsten—	
80/85%, carbon free	1/10 lb.
Tungsten metal powder—	
98/99%	2/3 lb.
Ferro-chrome—	
4/6% car.	£37 10
6/8% car.	£37
8/10% car.	£36 0
Ferro-chrome—	
Max. 2% car.	£84
Max. 1% car.	£100
Max. 0.75% car.	£115
65/75%, carbonless	2/9 lb.
Nickel—99·8%, cubes or pellets	£195
Cobalt metal—97%	19/0 lb.
Aluminium—98/99%	£150
Metallic Chromium—	
98/99%	6/6 lb.
Ferro-manganese—	
76/80%, loose	£20
76/80%, packed	£21
76/80%, export	£20
Metallic manganese—	
98/99%, carbonless	3/1 lb.

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

	s. d.
Finished bars, 14% tungsten	3 0
Finished bars, 18% tungsten	3 9
Scrap pieces	5d.
Turnings and swarf	3d.

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares 3 in. to 8 in. inclusive 4d. lb.
Rounds and squares under ½ in. to ¼ in. 3d. lb.
Flats under 1 in. by ⅜ in. to ½ in. by ¼ in., and all sizes over four times in width over thickness 3d. lb.
Bevels of approved sizes and sections 6d. lb.
If in coils 3d. lb.
Packing 4s. cwt
Bars cut to length 10% extra

Scrap from high-speed tool steel—

Scrap pieces 5d.
Turnings and swarf 3d.

Per lb. net, d/d steel makers' works.

SCRAP.

South Wales—	£ s. d.
Heavy Steel	4 0 0
Bundled steel & shearings	3 10 0
Mixed iron & steel	1 10 0
Heavy cast iron	4 0 0
Good machinery for foundries	4 15 0
	7 10 0
Cleveland—	
Heavy steel	3 5 0
Steel turnings	3 0 0
Cast-iron borings	3 0 0
Heavy wrought iron piling	5 15 0
Bundling scrap	5 5 0
Cast-iron scrap	7 5 0
Lancashire—	
Cast iron scrap	7 0 0
Heavy wrought	4 10 0
Steel turnings	2 10 0
London—	
Copper (clean)	50 0 0
Brass (clean)	29 0 0
Lead (less usual draft)	15 0 0
Tea lead	12 0 0
Zinc	12 0 0
New aluminium cuttings	75 0 0
Braziery copper	40 0 0
Gun metal	48 0 0
Hollow pewter	110 0 0
Shaped black pewter	65 0 0

PIG-IRON.

N.-E. Coast—	
Foundry No. 1	125/-
Foundry No. 3	120/-
Forge No. 4	117/6
Mottled	117/6
Hematite No. 1	182/6
Hematite M/Nos.	180/-
Midlands—	
Staffs. common	145/-
,, part-mine forge	160/-
,, ,, foundry	170/-
,, Cold blast	350/-
,, basic	140/-
Northants forge	140/-
,, foundry No. 3	147/6
,, basic	140/-
Derbyshire forge	150/-
,, foundry No. 3	160/-
,, basic	150/-
Scotland—	
Foundry No. 1	170/-
,, No. 3	165/-
Hematite M/Nos.	180/-
Sheffield (d/d district)—	
Derby forge	155/-
,, foundry No. 3	160/-
,, basic	155/-
Lincs. forge	160/-
,, foundry No. 3	170/-
,, basic	162/6
E.C. hematite	193/-
W.C. hematite	196/-

All d/d in the district.

Lancashire (d/d eq. Man.)—	
Derby forge	—
,, foundry No. 3	170/-
Northants foundry No. 3	—
Cleveland foundry No. 3	—
Staffs. foundry No. 3	—
Lincs. forge	172/6
,, foundry No. 3	177/6
Summerlee foundry	193/-
Glengarnock foundry	193/-
Gartsherrie foundry	193/-
Monkland foundry	193/-

FINISHED IRON & STEEL.

Iron—	£ s.	£ s. d.
Bars (cro'n)	19 0	24 10 0
Angles	19 10	25 0 0
Tees to 3 united ins.	20 0	25 10 0
Nut and bolt		20 0 0
Hoops		23 0 0
Marked bars (Staffs.)		27 10 0
Gas strip		26 0 0
Bolts and nuts, ⅜ in. × 4 in.		42 0 0
Steel—		
Ship plates		19 0 0
Boiler plates		25 0 0
Checquer plates		22 0 0
Angles		17 10 0
Tees		18 10 0
Channels		18 0 0
Joists		17 10 0
Rounds, ⅜ in.–3-in.		17 0 0
Rounds, 3 in.–5½ in.		16 0 0
Flats, 5 in.–8 in.		16 10 0
Flats over 8 in.		16 0 0
Rails, heavy		18 0 0
Fishplates		23 0 0
Hoops		18 10 0
Black sheets, 24 g.		21 10 0
Galv. cor. sheets, 24 g.		23 10 0
Galv. fencing wire, 8 g. plain		30 0 0
Rivets, ¾ in. dia		28 0 0
Billets, soft		13 10 0
Billets, hard		14 10 0
Sheet and tin bars		13 0 0

PHOSPHOR BRONZE.

Rolled.	Per lb. s. d.
½ in. to 1 in. wide	1 10½
1 in. to 1½ in. wide	1 10½
1½ in. to 2 in. wide	1 8¾

Strips.	s. d.
2 in. to 6 in. to 26 S.W.G.	1 8½
6 in. to 12 in. to 26 S.W.G.	1 8½

Sheets.	s. d.
12 in. to 18 in. to 24 S.W.G.	1 8½
18 in. to 24 in. to 24 S.W.G.	1 9¼
24 in. to 30 in. to 20 S.W.G.	1 10¼
30 in. to 36 in. to 16 S.W.G.	1 10¾
36 in. to 42 in. to 16 S.W.G.	1 11¾

Extras.

For Gauge: Any width up to 36 in. wide, ½d. per lb. per thinner gauge.

Drawn Rods.	s. d.
¼ in. to ½ in. dia. in random lengths ⅝ in. to 1½ in. dia. in random lengths	1 9
Over 1½ in. to 1¾ in.	1 9
Tubes—basis price	1 10¼

Delivery 2 cwt. free to any town.

10% phosphor copper, £40 above price of B.S.

15% phosphor copper, £50 above price of B.S.

Phosphor tin (5%), £30 above price of English ingots.

Charles Clifford & Son, Limited, Birmingham.

NICKEL SILVER, SHEET METAL, WIRE AND TUBES.

	Per lb.
Ingots for raising	1/3 to 1/9
Rolled—	
To 9 in. wide	1/10½ to 2/4½
To 12 in. wide	1/11 to 2/5
To 15 in. wide	2/- to 2/6
To 18 in. wide	2/1 to 2/7
To 21 in. wide	2/2 to 2/8
To 24 in. wide	2/3 to 2/9
Ingots for spoons and forks	1/3 to 1/9
Ingots rolled to spoon size	1/6 to 2/-
Wire round—	
3/0 to 10. G.	2/1 to 2/8

with extras according to gauge

AMERICAN IRON & STEEL.

At Pittsburgh unless otherwise stated.	Dols.
No. 2X foundry, Phila.	27.84
No. 2 foundry Valley	25.00
No. 2 foundry, Birm.	25.00
Basic	24.96
Bessemer	26.96
Malleable	26.96
Grey forge	25.96
Ferro-manganese 80 % delievred	90.00
Bess. rails, h'y, at mill	45.00
O.-h. rails, h'y, at mill	47.00
Bess. billets	38.00
O.-h. billets	38.50
O.-h. sheet bars	38.00
Wire rods	52.00
	Cents.
Iron bars, Phila.	2.45
Steel bars	2.00
Tank plates	2. 00
Beams, etc.	2.00
Skelp, grooved steel	2.25
Skelp, sheared steel	2.45
Steel hoops	2.80
Sheets, black, No. 28	3.85
Sheets, galv., No. 28	5.00
Sheets, blue an'l'd, 9&10	3.00
Wire nails	3.00
Plain wire	3.00
Barbed wire, galv.	3.85
Tinplate, 100-lb. box	$7.00

COKE.

Welsh foundry	72/6
,, furnace	57/6
Durham & North. foundry	70/-
,, furnace	42/6
Other Districts, foundry	77/9
,, furnace	45/-

SWEDISH IRON.

Bars, hammered basis sizes. Basis price £35 to £37

	£ s. d.
Rolled Ordinary—Assortment ..	26 0 0 to 27 0 0
Nail Rods—Square, round and flats ..	
Keg Steel / Faggot Steel	about £40 — Prices nominal.

Blooms—
Single welded .. £17 to £19

Billets—
Single and double welded .. £20 to £25

Pig-Iron—
Grey, white or mottled .. £14 to £16

Prices are without engagement. All quotations are f.o.b. Gothenburg, net cash against documents there.

TUBES.

	Up to and incl. 2 in.	Over 2 in.
Gas ..	—10%	—15%
Water ..	net	— 6¼%
Steam ..	+11¼%	+ 3¾%

TINPLATES.

I.C. Cokes,	20×14, box	25/-
,,	28×20, ,,	53/-
,,	20×10, ,,	37/-
,,	18¾×14, ,,	30/-
I.X.	,,	73/-
I.X.X.	,,	103-
F.C.B.Y.	21×13⅝ ,,	50/6
C.V.B.G.	16½×15, ,,	50/-
I.C.W.	20×14, ,,	18/6
,,	28×20, ,,	38/-
,,	20×10, ,,	28/-
,,	18¾×14, ,,	14/9
Terneplates,	28×20, ,,	£ 55/-

DAILY FLUCTUATIONS.

Standard Copper (cash).

	£	s.	d.		
Apr. 6	68	15	0	inc.	7/6
,, 7	69	0	0	,,	5/-
,, 8	68	17	6	dec.	2/6
,, 11	69	5	0	inc.	7/6
,, 12	69	0	0	dec.	5/-

Electrolytic Copper (Cash).

Apr. 6	71	10	0	dec.	20/-
,, 7	72	10	0	inc.	20/-
,, 8	72	10	0	No change	
,, 11	72	10	0	No change	
,, 12	72	10	0	No change	

Standard Tin (cash).

Apr. 6	154	10	0	inc.	40/-
,, 7	158	10	0	,,	80/-
,, 8	159	10	0	,,	20/-
,, 11	163	0	0	,,	70/-
,, 12	161	10	0	dec.	30/-

Tin (English Ingots)

Apr. 6	151	0	0	inc.	40/-
Apr. 7	154	10	0	inc.	70/-
,, 8	156	0	0	,,	30/-
,, 11	160	0	0	,,	80/-
,, 12	159	0	0	dec.	20/-

Zinc Sheets (spot).

Apr. 6	36	0	0	No change
,, 7	36	0	0	No change
,, 8	36	0	0	No change
,, 11	36	0	0	No change
,, 12	36	0	0	No change

Spelter (ordinary).

Apr. 6	24	15	0	inc.	15/-
,, 7	24	15	0	No change	
,, 8	25	7	6	inc.	12/6
,, 11	26	0	0	Inc.	12/6
,, 12	26	0	0	No change	

Lead (English).

Apr. 6	21	10	0	inc.	15/-
,, 7	21	15	0	,,	5/-
,, 8	22	0	0	,,	5/-
,, 11	22	5	0	,,	5/-
,, 12	22	5	0	No change	

SHROPSHIRE IRON Co., Ltd.

Works — Hadley, Shropshire.
London: 10, Bush Lane, Cannon St., E.C.4.

Telegrams :— Sun, Wellington, Salop. Sunbrand (Cannon), London.
Telephone :— 11 Wellington, Salop. 5959 Central.

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Galvanised Telegraph, Telephone, Cable and Trolley Wire
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Delivered F.O.B. Liverpool.
BARS, ANGLES, TEES and PLATES.

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SITUATIONS VACANT AND WANTED.

FOREMAN PATTERNMAKER (40), desires re-engagement; good organiser and controller. Exp. Motor, Marine, Cent. Pumps, and Loam.—Box 722, Offices of the Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

STEEL FOUNDRY FOREMAN REQUIRED for new foundry to produce 50 tons castings per week: must be energetic and capable of taking full charge of moulding, Tropenas plant and fettling.—Full particulars of age, experience, and salary required to CLAYTON & SHUTTLEWORTH, Ltd., Lincoln.

MACHINERY.

TURN TO THE B.W.S. ANNOUNCEMENT, PAGE 12.

"FARWELL" HAND-SQUEEZE MACHINE Wanted.—Write, giving full particulars, to Box 724, Offices of the Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

MARINE BOILERS.—
FOR SALE Single-ended BOILERS, 13 ft. by 11 ft. 3 in.
Three corrugated furnaces, Deighton type.
Howden's forced draught.
Working pressure 200 lbs.
First-class condition as practically new, and Lloyds will accept as new from instalment.
Apply, Robinson Brown & Company, Newcastle-on-Tyne.

SACRIFICE.—One No. 2 Swinghead Pneumatic Moulding Machine by Rudman, Lancey & Craven, Taunton. Practically new. Will sell for first reasonable offer.—Photo and particulars from E. & H. Roberts, Ltd., Deanshanger Ironworks, Stony Stratford.

FOR SALE.

350-KW. GENERATING SET, by Scott & Mountain, Compound Engine direct coupled to Generator, 230 volts, 350 revs.

250-KW. "BELLIS & MORCOM" GENERATING SET, Triple Expansion Engine, d.c. to Generator, 460/550 volts, 380 revs.

Two 80-KW "BELLIS" GENERATING SETS, Compound Vertical Engine, d.c. to Generator, 460 volts, 163 amps., 440 revs.

Two 25-KW. "BELLIS" GENERATING SETS, two Dynamos to each Engine, 230/460 volts, 52 amps., 460 revs.

Pair of HORIZONTAL STEAM ENGINES, 11-in. cyls., 14-in. stroke, by Robey & Company.

HORIZONTAL STEAM ENGINE, 18-in. cyls., 36-in. stroke, by E. R. & F. Turner.

One 5 ft. arm RADIAL DRILLING MACHINE, by W. Muir & Company.

Nearly new WORTHINGTON HORIZONTAL DUPLEX PUMP, 16 in. x 10½ in. x 10 in.

Nearly new WORTHINGTON HORIZONTAL DUPLEX PUMP, 7½ in. x 5 in. x 6 in., with Gun Metal boxes.

Diesel Engines.

Fan Engines and Fans, Steering Gears, Ash Hoists, Turbines from 2,000 to 10,000 h.p.

Condensing Plants.

Large number of Weir Pumps in various sizes, ranging from 6 in. to 14 in. cyl., 6 in. to 12 in. stroke.

CATALOGUE OF STOCK MACHINERY, 5-6,000 LOTS, FREE ON APPLICATION. INSPECTION INVITED.

THOS. W. WARD, Ltd.,
ALBION WORKS, SHEFFIELD.
Telegrams: "Forward, Sheffield."
Telephone: 4321 (8 lines).

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ORDERS WANTED for small Machine-made Castings in Brass, Gunmetal, Phosphor, or Manganese Bronze. Also Castings any size up to one ton in weight. Prompt delivery.—James G. Crowther, Paradise Street Brass Foundry, Sheffield.

CASTINGS (IRON) ORDERS WANTED for any weight and size (Yorkshire District). Machines if necessary.—Address, Box 728, Offices of the Foundry Trade Journal, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

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ENQUIRIES SOLICITED FOR CASTINGS IN IRON, machined or unmachined, up to 5 cwt. Complete Machines built throughout to specification, singly or in quantity. Jig and Tool Work a speciality.—C. S. Peatfield, Limited, Market Rasen, Lincs.

PATTERNS and CASTINGS SUPPLIED WHICH GIVE SATISFACTION. Inquiries solicited. Quotations by return of post or telephone. You can secure good-class work, reasonable prices, and promptitude in delivery by placing your orders with Videx Pattern Works and Foundry, Huntsworth Mews, Upper Baker Street, London, N.W.1. (Telephone, Paddington 364).

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WE Specialise in FANS and FAN WORK for Foundries. H.P. Fans and Blowers for Smiths' Hearths, Cupolas, Oil and Gas-fired Furnaces, Dust Extraction Fans for Fettling Shop and Sand Blast, Ventilating Fans for Fumes, etc. Worm-geared Pulley Blocks, 10 cwt. to 10 tons.—Progressive Engineering Company, Limited, Leicester.

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THE PROPRIETORS of the Patent No. 3,786, of 1915, for Heat Treatment of Manganese Steel, are desirous of entering into arrangements, by way of licence and otherwise, on reasonable terms, for the purpose of exploiting the same and ensuring its full development and practical working in this country.—All communications should be addressed in the first instance to Haseltine, Lake & Co., Chartered Patent Agents, 28, Southampton Buildings, Chancery Lane, London, W.C.

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